NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

JOINT APPLIED PROJECT

Employing Organizational Modeling and Simulation to Deconstruct the KC-135 Aircraft's Programmed Depot Maintenance Flight Controls Repair Cell

---

By: Matthew A. Paskin
Alice W. Treviño

December 2007

Advisors: Geraldo Ferrer
John T. Dillard

Approved for public release; distribution is unlimited.

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*
Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.			
1. AGENCY USE ONLY ***(Leave blank)***	**2. REPORT DATE** December 2007	**3. REPORT TYPE AND DATES COVERED** Joint Applied Project	
4. TITLE AND SUBTITLE Employing Organizational Modeling and Simulation to Deconstruct the KC-135 Aircraft's Programmed Depot Maintenance Flight Controls Repair Cell			**5. FUNDING NUMBERS**
6. AUTHOR(S) Paskin, Matthew A. and Treviño, Alice W.			
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000			**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES) N/A			**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**
11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.			
12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited			**12b. DISTRIBUTION CODE** A
13. ABSTRACT (maximum 200 words) This research modeled and simulated the KC-135 aircraft's Programmed Depot Maintenance (PDM) Flight Controls Repair Cell to identify improvement opportunities for greater efficiency within the flight controls repair process. PDM is conducted by the 564th Aircraft Maintenance Squadron, 76th Aircraft Maintenance Group, Oklahoma City Air Logistics Center (OC-ALC), Tinker Air Force Base, Oklahoma. The researchers focused on the repair cell's internal formal and informal communication flows and information processing to evaluate the impact on flight controls repair throughput time. Computational organizational modeling was employed to examine organizational design modifications and their effect on repair cycle-time, project cost, and project risk. The modeling and simulation software used is based upon organizational design theory and information-processing research. To build the baseline organizational model that emulated the actual repair process, the researchers collected data through interviews with repair cell personnel and through observation of the repair process. Modifications called "interventions" were developed to simulate and analyze organizational design changes. The study concludes with the recommendation of feasible organizational design alternatives for OC-ALC decision-makers to improve the flight controls repair process and throughput time.			
14. SUBJECT TERMS Air Force Smart Operations for the 21st Century (AFSO21), Computational Organizational Theory, Organizational Modeling, Simulation, Organizational Design, Information Processing and Knowledge Sharing, Throughput and Cycle-Time, Virtual Design Team (VDT), KC-135 Stratotanker, Programmed Depot Maintenance (PDM)			**15. NUMBER OF PAGES** 168
			16. PRICE CODE
17. SECURITY CLASSIFICATION OF REPORT Unclassified	**18. SECURITY CLASSIFICATION OF THIS PAGE** Unclassified	**19. SECURITY CLASSIFICATION OF ABSTRACT** Unclassified	**20. LIMITATION OF ABSTRACT** UU

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

EMPLOYING ORGANIZATIONAL MODELING AND SIMULATION TO DECONSTRUCT THE KC-135 AIRCRAFT'S PROGRAMMED DEPOT MAINTENANCE FLIGHT CONTROLS REPAIR CELL

Matthew A. Paskin, Major, United States Air Force
A.A., Kingsborough Community College of the City University of New York, 1993
B.A., Hunter College of the City University of New York, 1995
M.A., The George Washington University, 2003

Alice Ward Treviño, Major, United States Air Force
B.S., United States Air Force Academy, 1993
M.A., Webster University, 1997
M.A., Webster University, 1997

Submitted in partial fulfillment of the requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
December 2007

Authors: ________________________________
Matthew A. Paskin

____
Alice Ward Treviño

Approved by: ________________________________
Geraldo Ferrer, Co-Advisor

____
John T. Dillard, Co-Advisor

____
Robert N. Beck, Dean
Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

EMPLOYING ORGANIZATIONAL MODELING AND SIMULATION TO DECONSTRUCT THE KC-135 AIRCRAFT'S PROGRAMMED DEPOT MAINTENANCE FLIGHT CONTROLS REPAIR CELL

ABSTRACT

This research modeled and simulated the KC-135 aircraft's Programmed Depot Maintenance (PDM) Flight Controls Repair Cell to identify improvement opportunities for greater efficiency within the flight controls repair process. PDM is conducted by the 564th Aircraft Maintenance Squadron, 76th Aircraft Maintenance Group, Oklahoma City Air Logistics Center (OC-ALC), Tinker Air Force Base, Oklahoma. The researchers focused on the repair cell's internal formal and informal communication flows and information processing to evaluate the impact on flight controls repair throughput time. Computational organizational modeling was employed to examine organizational design modifications and their effect on repair cycle-time, project cost, and project risk. The modeling and simulation software used is based upon organizational design theory and information-processing research. To build the baseline organizational model that emulated the actual repair process, the researchers collected data through interviews with repair cell personnel and through observation of the repair process. Modifications called "interventions" were developed to simulate and analyze organizational design changes. The study concludes with the recommendation of feasible organizational design alternatives for OC-ALC decision-makers to improve the flight controls repair process and throughput time.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF ABBREVIATIONS, ACRONYMS, SYMBOLS

564 AMXS	564th Aircraft Maintenance Squadron
AFMC	Air Force Materiel Command
AFSO21	Air Force Smart Operations for the 21st Century
AIMD	Aircraft Intermediate Maintenance Division
ALC	Air Logistics Center
ALS	Aircraft Logistics Specialist
AM2	Two Aircraft Mechanics
AM7	Seven Aircraft Mechanics
AM9	Nine Aircraft Mechanics
APTS	Aircraft Parts Tracking System
CBA	Collective Bargaining Agreement
DoD	Department of Defense
ERRC	Expendability, Recoverability, Repairability Code
FLS	Forward Logistics Specialist
FTE	Full-Time Equivalent
HV	Horizontal/Vertical
IPV	Industrial Prime Vendor
MBA	Masters of Business Administration
NAS	Naval Air Station
NDI	Nondestructive Inspection
NPS	Naval Postgraduate School
OC-ALC	Oklahoma City Air Logistics Center
OPM	Office of Personnel Management's
PCU	Power Control Unit
PDM	Programmed Depot Maintenance
PDMSS	Program Depot Maintenance Schedule System
pm	Project Manager
PN	Planner
PS	Production Supervisor
sl	Subteam Lead
SM	Sheet Metal Mechanics
st	Subteam
TL	Team Leader
USAF	United States Air Force
VDT	Virtual Design Team
WCD	Work Control Document

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

Through the endless encouragement, love, and understanding of our families, Ray Treviño, and Allie and Liberty Paskin, our project was built solidly and supported wholeheartedly from day one. The lifestyle that a military family lives can be more than difficult at times; your strength and dedication enabled us to better ourselves through the education learned from completing this project.

We especially thank our advisors Doctor Geraldo Ferrer and Professor John Dillard for their supportive recommendations, inimitable guidance, and invaluable counsel. Letting us explore the educational and applied uses of our theories without constraint allowed us to produce a project for which we feel pride and a huge sense of accomplishment. We also thank Professor Diana Petross for her organizational insights and priceless use of her office during our project to contact the KC-135 aircraft's Flight Controls Repair Cell team members. Additionally, we thank Professor Susan Heath, our modeling and simulation instructor, for providing a solid education foundation upon which to build. You gave us the ability to translate problems into simulation models and analyze the strengths and weaknesses of the simulation results.

Graciously, we thank Karey Shaffer and the entire Acquisition Research Program for their helpfulness, program information, and financial support. A special thanks to Retired Rear Admiral Jim Greene, the Naval Postgraduate School Acquisition Research Chair, for securing the sponsor funding for our research. We greatly appreciate the SimVision/POWer Team from Stanford University—to include Doctor Roxanne Zolin—for developing a powerful and robust computational model, without which our project would be insufficient.

We owe enormous gratitude to Garry Richey (Senior Executive Service), Brigadier General Judy Fedder, Colonel Casey Hughson, Clint Gill, Dan Mooney, and Major Greg Allen for their transformational leadership and sponsorship by granting us unfettered access to the members of the Oklahoma City Air Logistics Center. Moreover, we are grateful to Debi Kirkpatrick, Steve Stoner, Robert Johnson, Kenneth Dunn, and Brian Defonteny for vectoring us in the right direction and supporting us throughout the

project. In addition, to James Wilson, Debbie Welch, Tom Williams, Cynthia Grant, Charlette Moody, Ralph Feltman, Tom Gallagher, Michael Rehder, Phil Duncan, Jeff Kerchee, Rick Wood, Eric Little, and Jesse McGaha, we are indebted for your insights and candidness of the flight controls repair process and the nuances of how you fulfill your responsibilities. Your enthusiasm and dedication for persistent improvement contributes to the effectiveness of the United States Air Force. To all the wonderful people at the Oklahoma City Air Logistics Center and Tinker Air Force Base, we are forever grateful for your hospitality and immeasurable assistance throughout our research endeavor and learning experience.

Finally, thank you Lieutenant Colonel Joel Hagan and Captain Bill Slack for inspiring our educational odyssey and answering a multitude of questions to kick-start our research.

I. INTRODUCTION

A. BACKGROUND

The 564th Aircraft Maintenance Squadron (564 AMXS) is a unit assigned to the Oklahoma City Air Logistics Center (OC-ALC) and is responsible for the United States Air Force (USAF) KC-135 aircraft's Programmed Depot Maintenance (PDM). Within the 564 AMXS, the KC-135 Flight Controls Repair Cell (referred to as the Horizontal/Vertical (HV) Repair Cell throughout this paper) is responsible for refurbishment of the aircraft's vertical and two horizontal stabilizers.

As stated by Air Mobility Command's Public Affairs Office, the Boeing KC-135 Stratotanker's principal mission is air refueling of Department of Defense (DoD) and allied nations' aircraft. In addition to the aircraft's principal mission, KC-135 units conduct nonrefueling missions such as: transporting military troops, cargo, supplies; supporting aero medical evacuations; and "providing Beyond Line of Sight data link capability" (827th Aircraft Sustainment Group, 2007). For example, in July 2007, the 100th Air Refueling Wing at RAF Mildenhall, England, "transported a total of 86 passengers to and from Kosovo and Romania, while also delivering more than 5,000 pounds of cargo and a couple of gallons of blood" (Ziezulewicz, 2007, p.1). Over the last six years, the number of these types of missions has risen dramatically in support of Operation Noble Eagle, Operation Enduring Freedom, Operation Iraqi Freedom, and Horn of Africa operations.

As a result of increased operations tempo, both refueling and nontraditional taskings continue to stress the aging KC-135 fleet. According to a recent US Government Accountability Office Report, "the KC-135 fleet averages more than 46 years and is the oldest combat weapon system in the Air Force inventory" (Solis, Borseth, Coleman, Mardis, & Thornton, 2007, p. 1). Furthermore, as indicated by Laredo, Pyles, and Snyder's RAND Corporation research (2007) regarding PDM capacity and workload growth, issues arise when aircraft are kept beyond the age the USAF has experience in maintaining.

Recently, USAF maintenance organizations like the 564 AMXS are gaining more familiarity with operating aircraft more than 45 years old out of necessity because "…current plans call for operating portions of the KC-135 fleet until about age 80" (Laredo, Pyles, & Snyder, 2007, p. 84). With an 80-year lifespan expectancy, maintaining aging aircraft by the most cost-effective and efficient means continues to be a difficult challenge.

The USAF must deftly balance funding limitations, priorities, and Congressional guidance. For instance, in an Air Force Magazine article by Scully (2007), the USAF plans to retire all 85 KC-135E aircraft in the inventory during 2007 because they currently average 49.4 years old. Moreover, according to the AFM defense reporter, if the 85 KC-135E's are not grounded by the end of Fiscal Year 2010, the aircraft's Expanded Interim (strut) Repairs will expire and cost the USAF:

> ... an additional $17.3 million per aircraft—totaling a pricey $1.4 billion for the entire fleet. And at the end of the day, those KC-135s would then average 53 years old. Last year, Congress allowed the Air Force to retire 29 of the KC-135Es and 51 C-130Es, but required the service to maintain all of the airframes at a state that would allow them to be called back to service. (Scully, 2007, p. 53)

In line with these rigorous operating and maintenance expectations, the 564 AMXS mission is to provide customers with top-quality aircraft on-time and at the best value (76th Aircraft Maintenance Group, 2007). Organizational units, including the HV Repair Cell, are aligned to work together towards KC-135 PDM schedule execution, customer requirements, and continual infrastructure improvement that enhance production support.

The HV Repair Cell faces multiple complexities resulting from evolving mission requirements, financial pressures, workforce reductions, the aforementioned aging KC-135 fleet, and continuous demands to identify and eradicate waste. Although the unit's current organizational design is structured to support mission accomplishment, alternative design changes may enhance performance and/or timeliness. HV Repair Cell design changes may support the overall 564 AMXS' transformational efforts.

According to the official USAF website, "transformation is a process by which the military achieves and maintains an advantage through changes in operational concepts, organization, and/or technologies that significantly improve its warfighting capabilities or ability to meet the demands of a changing security environment" (HAF/XPXC, Air Force Transformation Office, 2007). Transformation efforts provide value and remove non-value-added activities in order to enhance the USAF's abilities to accomplish the mission. As a result, organizations like the HV Repair Cell are better able to respond to ever-changing demands, free-up resources for future modernization, and eliminate waste in organizational processes.

The OC-ALC supports USAF transformation through its Transformation Office. The Tanker Lean Office Agent, Kenneth Dunn, provides specific details from the May 2006 Business Unit Plan Development Team established with the 564 AMXS, Battelle, Association of Federal Government Employees and union membership. This partnership benefits from the 564 AMXS' experience in maintaining C/KC-135 aircraft and Battelle's private industry expertise to transform operations (K. Dunn, personal communication, June 1, 2007). Currently in its final stages, Dunn explains the details of the team's overarching transformation plan for future tanker-maintenance performance expectations, including:

- Workload Throughput: minimum of 48 aircraft per year
- Maintenance Flow-days: 100 calendar days
- Work-in-progress: maximum of 17 aircraft
- Supply Response: serviceable parts received for installation in less than 48 hours after ordered from supply

OC-ALC senior leaders and KC-135 PDM management expressed interest in additional approaches to improve KC-135 PDM operations and invited the Naval Postgraduate School (NPS) to conduct this research. Since the 564 AMXS maintains the USAF's oldest combat weapon system—and will do so for nearly four more decades—the unit is receptive to research that identifies possible organizational and process-improvement recommendations to support the KC-135's continued operation. An analysis of the organization is used to assess the HV Repair Cell's employment of

information channels; leverage of communication avenues across repair cell functions and information-sharing; and transfer of task, skill-level, and process information between personnel.

This paper presents the results of using computational organizational modeling and simulation as an alternative methodology to support the 564 AMXS transformation initiatives by examining the aircraft's flight controls repair process. The researchers use POWer 3.0a software developed by the Virtual Design Team at Stanford University. The model is discussed in greater detail within the Scope section and Literature Review chapters.

B. RESEARCH OBJECTIVE

The objective of this research is to provide the KC-135 HV Repair Cell with feasible alternatives for decision-makers regarding organizational design to decrease flight controls repair throughput time, cost, and risk. To meet this objective, this project develops a computational organizational model of the flight controls repair operation that emulates the current maintenance process. The model helps identify: potential problems; hotspot areas increasing project duration, risk, or cost; positions with work backlog affecting decision bottlenecks; and alternative avenues to improve KC-135 flight controls repair throughput time. The model is then modified to characterize the benefits and implications of organizational design interventions on improving the flight controls repair process and throughput time.

C. SCOPE

This Master's of Business Administration (MBA) joint applied project only considers the portion of the KC-135 PDM organization and processes that accomplish flight controls maintenance. The report and modeling effort take into account maintenance and administration tasks beginning when the HV Repair Cell receives the vertical and two horizontal stabilizers (after removal from the aircraft) and ending when the repair cell deems the stabilizers serviceable and ready for reinstallation on the KC-135. Additionally, the model only includes personnel assigned to the flight controls repair cell and only represents the repair of one set of horizontal and vertical stabilizers.

While the repair cell typically processes up to six sets of stabilizers at once, the information collected from unit personnel involves one individual set.

Modeling and simulation of the flight controls repair operation is undertaken using unique POWer 3.0a software developed by the Stanford University Virtual Design Team led by Dr. Raymond E. Levitt and Dr. John C. Kunz. POWer is used because it quantitatively models work processes, information and communication exchanges, and organizational behavior. The software integrates direct work tasks, coordination, and rework into an amount of information for processing by organizational members.

According to Levitt (2007), workers process information during the simulation based on the modeler's settings in POWer addressing. The modeler assesses how coworkers communicate, how decision-making responsibility is handled, skill-level relative to associated tasks, team experience, and organizational culture. After running the model, outputs reveal hidden work, project risk, functional risk failure points, and position backlog. The software's capabilities and limitations drive the results of the research to model design changes within the KC-135 Flight Controls Repair Cell. No attempt was made to modify or alter the POWer 3.0a software.

D. METHODOLOGY

The authors' methodology is divided into four major phases:

1. An extensive literature review is conducted to understand and become familiar with: organizational design theory and information flow research; computational organizational modeling theory; the Virtual Design Team's research and methods, and previous NPS researcher's organizational modeling techniques. The literature review establishes the necessary foundation to develop the KC-135 Flight Controls Repair Cell organizational model.

2. After becoming familiar with the POWer 3.0a software, the researchers performed a site visit to the KC-135 aircraft's PDM Flight Controls Repair Cell, 564 AMXS, OC-ALC at Tinker Air Force Base, Oklahoma. Interviews with unit

personnel contributed to data collection and increased the researchers' understanding of the HV Repair Cell's process and organizational design. A description of the modeled organization is provided in Chapter III.

3. Using information collected during the site visit, telephonic and electronic mail exchanges, the authors developed a baseline model. The eProjectManagement's *SimVision Users' Guide* (2003) and the Collaboratory for Research on Global Projects' POWer Documentation for POWer 2.0 (2006) references explain how to construct a baseline model and describe model characteristics and parameters used in the baseline model. (Note: specific POWer 3.0a software documentation is not available from Stanford University for this research).

4. Based on their discussions with HV Repair Cell personnel and the insights they gained into current organizational operations and resource constraints, the researchers identified possible organizational design "interventions." The baseline model is used to assess the strengths and weaknesses of potential changes with regard to eight output parameters: project duration, direct work time, indirect or hidden time (measured by rework time, coordination time, exception-handling wait time), total direct and indirect work time, total project cost, total functional and project exception time (measured by functional exception work and project exception work), project risk, and position backlog.

E. ORGANIZATION OF RESEARCH

This paper is organized into five chapters. The first chapter introduces the project by describing the background, research objective, scope, and methodology. The second chapter is the literature review. It supplies general background information about computational organizational modeling and specific organizational modeling techniques employed within POWer software developed by Stanford University's Virtual Design Team. The third chapter discusses methodology. The fourth chapter describes the results. Finally, the fifth chapter reveals the conclusions and recommendations provided for the HV Repair Cell.

Data is collected, analyzed, and entered into the POWer organizational modeling and simulation software to establish a baseline model. The simulation's results help identify weaknesses regarding anticipated project duration, amount of position backlog, cost, and risk. These results highlight potential areas of improvement to assist decision-makers with developing organizational design modifications that will improve the KC-135 flight controls repair process and throughput time. Possible design changes are identified as interventions. Then, the baseline is modified to assess projected organizational impacts.

THIS PAGE INTENTIONALLY LEFT BLANK

II. LITERATURE REVIEW

This literature review examines Jay R. Galbraith's organizational design and information-processing research; background on computational organizational modeling; and the Virtual Design Team's (VDT) development, methodology and validation of computational organizational modeling software. Additionally, the literature review includes previous research using computational organizational modeling and simulation by Hagan and Slack (2006) in the Aircraft Intermediate Maintenance Division (AIMD) at Naval Air Station (NAS) Lemoore, California, and by Dillard and Nissen (2007) "to assess the behavior and project performance of different organizational designs in varying environments" (p. 5).

A. THEORETICAL BASIS

Galbraith's (1977) organizational design and information-processing research is based heavily on three schools of thought: the classical school of management developed in the 1960s; the human relations school stemming from Harvard University's Hawthorne studies conducted by Roethlisberger and Dickson in the 1930s; and the "people approach" evolving to some extent from human-relations theory and 1960s research by Berlew, Hall, and Schein, coupled with a 1974 study by Edstrom and Galbraith.

The classical theory focuses on the mechanical structures of organizational design, such as division of labor, lines of authority, and centralized versus decentralized decision-making (Galbraith, 1977, pp. 13-15, 18). In comparison, Galbraith states the human-relations theory focuses on designing an "informal or humanistic organization" (pp. 23-24) through employing supportive behavior, fostering cohesive teams, and involving employees in conjunction with mechanistic structures. Finally, the people approach to designing organizations expands human-relations theory by concentrating more on the personnel (i.e., the employees) responsible for improving the organization's performance and how best to hire, promote, assign, train, and develop them (Galbraith, 1977).

Galbraith (1977) states that the Hawthorne studies originated the theory that performance levels vary depending on relations between and among group members, subordinates, and supervisors. Additionally, he incorporates previous research conducted by Bernard, Simon, and March in 1958 and 1963, which developed the theory that organizational decision-making and information-processing reflect "people's limited ability to process information" (Galbraith, 1977, p. 24). Personnel can only deal with a certain quantity of facts and figures before reaching overload or releasing one of the pieces of information to make room for a new piece.

Galbraith's research (1977) identifies five design variables underlying organizational design: task, structure, information and decision process, reward systems, and people. These five variables are interdependent because "a change in one can cause a change in the others for the better or for the worse" (Galbraith, 1977, p. 27) within the organization.

For example, Galbraith (1977) suggests that before designing an organization, managers should consider how many subordinate roles supervisors can coordinate effectively. One view maintains that human cognitive limitations support a maximum number of subordinates that supervisors can manage. Therefore, the number of employees one supervisor coordinates should be limited. An alternative view suggests that "the smaller the span, the greater the number of nonproductive roles that must be offset by the greater efficiency generated by the division of labor" (Galbraith, 1977, p. 17). When a manager considers both views, he or she can affect organizational decisions regarding task set-up, job delegation, information sharing, employee training, and performance appraisals. Moreover, ensuing design-variable decisions influence the organization's performance and effectiveness.

Additionally, Galbraith (1977) discusses decision-making, communication, and accountability within organizations. Staff specialists are normally responsible for "how" to conduct operations, while line managers are typically responsible for the more detailed "what and when" decisions to conduct operations. The "what and when" decisions surrounding operations are more esoteric than the "how" decisions. For instance, line managers may have to resolve conflicts regarding line and staff misunderstandings or

misinterpretations over staff directives. In contrast, Galbraith's research reveals how customary practices often change as a result of design variables and differences in information flow patterns. Specifically, "studies found that task variability, diversity, or difficulty were systematically related to structure, leadership style, personality, and decision processes" (Galbraith, 1977, p. 31).

By changing decision-making paths, modifying employee responsibilities, or organizing tasks differently, managers can affect individual understanding and performance, thus impacting the overall organization's operations. Galbraith (1977) concludes that organizations must strategically manage and periodically adjust the five interrelated design factors to function effectively. He ascertains that the ideal design methods to improve information-processing capacity "were to invest in the formal, hierarchical information process and to introduce lateral decision processes" (Galbraith, 1977, p. 56). Lastly, when faced with environmental and technological uncertainty, organizations must consider the tradeoffs of obtaining and sharing information to achieve certain levels of information-processing capability.

B. RATIONALE BEHIND COMPUTATIONAL ORGANIZATIONAL MODELING

According to Thomsen, Levitt, Kuntz, Nass, and Fridsma (2003), organizational theory encompasses the study of aggregate behaviors between large and small organizations and the individuals interacting within those organizations. Computational organizational theory uses computer tools to better understand the relationship of organizational micro- and macro- theories and behavior (Thomsen et al., 2003). This type of analysis is known as computational organizational modeling.

In the 1980s, Dr. Raymond Levitt formed Stanford University's Virtual Design Team (VDT) to investigate how to predict organizational behaviors using computational organizational modeling. The VDT team based its computational organizational framework on Galbraith's (1974; 1977) information-processing concepts. Their research uses computational organizational modeling to examine work processes and information flows associated with project- or task-based organizations (Nissen & Levitt, 2002).

According to Kuntz, Christiansen, Cohen, Jin, and Levitt (1998), Galbraith (1977) asserts that organizations possess limited abilities to process exceptions (which are requests for advice or direction when local knowledge or authority is insufficient to deal with the information processing requirements) while accomplishing organizational tasks. The VDT incorporates Galbraith's (1977) view regarding exceptions-processing into the computational model. Through functional and project exception probabilities, the VDT's computational model simulates task and project failures and subsequent rework when organizational knowledge or authority is inadequate. The unique benefit of POWer software is that organization decision-makers can view simulated design changes and projected risk or rework levels before they actually implement design changes in their organizations.

1. Premise of the Model

The intent of the VDT model is to provide a tool for managers to design organizations "the same way engineers design bridges: by building and analyzing computational models of planned organizations and the processes that they support" (Kuntz et al., 1998, p. 84). In this way, the VDT extends organizational theory, whereby individual organizational entities—such as actors, activities, and both direct and coordination work—are considered in the model's predictions (1998).

The VDT constructs a computational model that emulates real-world situations within the organization (Nissen & Levitt, 2002) and provides a capability to test through simulation and evaluate structural and task modifications. Thus, managers can identify the effects the changes have on interdependent activities to later avert cost overruns and quality failures (Levitt, 2004). Additionally, managers can identify unanticipated volumes of coordination and rework occurring from overlapping highly interdependent tasks. According to Levitt and Kuntz (2002), "this coordination and rework is hidden effort: it is not planned, tracked, managed or even acknowledged except by the overworked staff" (p. 4).

In Kuntz et al.'s (1998) view, the premise of the VDT model stems from the view that organizations are fundamentally information-processing structures supported by

information-processing and communication tools. Consequently, "an organization is an information-processing and communication system, structured to achieve a specific set of tasks, and composed of limited teams (actors) that process information" (Kuntz et al., 1998, p. 85). The VDT's model simulates each activity being performed by responsible actors and computes overall project duration, cost, and coordination quality (1998). Additionally, their simulation helps bridge the gap between organizational theory and experience at the micro- and macro-levels.

2. Description of Model Operation

This section describes an overview of the VDT's model operation and summarizes Kuntz et al.'s 1998 article. The VDT extends Galbraith's (1977) notion of communication channels by modeling relationships among actors. Actors are each supported by communication tools. Functional attributes of actors affect the timing and quality of information transfer across communication channels. Actors are modeled in terms of capability, actions, and organizational roles.

Inputs to the VDT model transform qualitative attribute values into quantitative values. These inputs are based on activities that consume time and may (or may not) generate communications and exceptions. Exceptions occur in the model when a worker detects a task requiring additional information or a decision or when the model generates an error that may need correcting by the worker. The VDT model assigns all actors a processing speed and a verification failure probability. During the verification process, failure probability determines when a sub-activity within an overall activity will fail.

Additionally, the VDT model incorporates activity coordination requirements among actors. Coordination requirements are measured in terms of verification failure probability that results from complex activities (i.e., uncertain and interdependent) and communication intensity. Coordination requires transfer of information between and among actors. Actors can communicate information received and processed by other actors. The VDT model labels communications as "work communications" or "coordination communications."

According to Kuntz et al. (1998), when the simulation completes a sub-activity, it stochastically determines whether or not it failed based on the verification failure probability input. If the sub-activity fails, a failure exception is generated. A failure exception initiates an "exception-decision" process. The VDT simulation requires managers to decide whether to rework or ignore the exception, which translates to the actor via a "decision communication." This decision may add more time and complexity to an actor's task.

At the end of the simulation, the model produces actions and interactions among actors and shows the organization's behavior and performance. Kuntz et al. (1998) proclaim the actor's information-processing and exception-handling form the core of the VDT micro-theory framework and establish the model's usefulness. The VDT framework is supported by Galbraith's (1973, 1974) theory that organizations serve as "exception-handling machines" as part of his information-processing view of organizations. Based on their conceptualization of Galbraith's theory, the VDT's "approach simulates the direct work and the hidden work, i.e., the coordination, supervision, rework and waiting for all the actors in a project as they perform all of the project tasks" (Levitt & Kunz, 2002, p. 11).

3. VDT's Methodology

As outlined by Levitt and Kunz (2002), there are four steps in the VDT's methodology: (a) define baseline work process and organization, (b) simulate project to assess risks for baseline case, (c) flight-simulate alternative management interventions, and (d) refine and archive model to capture lessons learned.

Documenting baseline assumptions helps capture the total effort required to complete an organization's project. Baseline assumptions include identifying: critical milestones, workflow and decision-making policies, information required to be processed by position personnel, and allowance for rework that spreads between parallel tasks as changes or errors occur (Levitt & Kunz, 2002).

In the second step, modelers simulate the data collected to establish a baseline model best representing the current organization. The baseline's results help identify

organizational risks and potential interventions to apply to the model that may mitigate those risks. Step Three simulates separate or combined alternative interventions to evaluate output for potential organizational performance improvements. Finally, Step Four establishes the model's calibration and validity as a reusable template to analyze current circumstances and predicted design modifications. According to an additional VDT study by Thomsen et al. (2003), the model's validity characteristic suggests that two different modelers given the same organization will be able to reproduce the same results.

4. Validation of VDT Model

The VDT demonstrated the model's validity by applying an emulation-based simulation model called Virtual Team Alliance (VTA) to the Lockheed Launch Vehicle Project (LLVP). Using a natural history experimental approach, team members applied the model to the ongoing project and performed a series of experiments to produce forward predictions about the LLVP's remaining tasks. The natural history method is more robust than retrospective experiments that duplicate past performance because the researcher cannot "curve fit" calibration parameters to unknown future performance benchmarks (Thomsen et al., 2003).

During the LLVP test, the VTA predicted backlog risks, quality problems, and potential delays in teams (outside of Lockheed) developing outsourced components, including the flight-box (Nissen & Levitt, 2002; Thomsen et al., 2003). Although these predictions were provided to LLVP managers, their inexperience with the VTA's modeling methodology prevented them from taking any intervening actions (Nissen & Levitt, 2002).

According to Nissen and Levitt (2002) and Thomsen et al. (2003), when the backlog and its impacts later materialized exactly as predicted, they severely impacted the LLVP's cost and schedule. Additionally, "during the demonstration launch, the launch vehicle veered off-course, and range control operators detonated the vehicle, along with its commercial payload" (Thomsen et al., 2003, p. 15). Post-launch investigation and data analysis revealed the mishap was caused by cable and flight-box problems under the subcontractor's responsibility. The VTA correctly predicted this area

was at higher risk for product quality. This study provided evidence of the VTA's validity and predictive power, which could be used to change future results based on predicted simulation outcomes.

C. ADDITIONAL ORGANIZATIONAL MODELING RESEARCH

Research conducted by Hagan and Slack (2006) and Dillard and Nissen (2007) recommends using computational organizational modeling to assist managers in identifying methods of improving information flow to enhance organizational performance.

Additionally, Hagan, Slack, Dillard, and Zolin (2007) provide further insight into the implications of computational organizational modeling. Computational organizational modeling enables leaders and managers to model and simulate planned organizational changes, evaluate prospective changes, calculate the impact, and determine if potential benefits are worth the costs and risks. NAS Lemoore's AIMD leaders' implementation of Hagan and Slack's recommendations and subsequent improvement to the F414 engine repair further demonstrated the VDT software's usefulness. Additionally, Hagan and Slack's research (2006) supports the U.S. Navy's transformation efforts.

Their project inspired this current research to explore a specific USAF organization utilizing Stanford University's 3.0a POWer software, the most current edition of the VDT tool. In addition, the authors examined Dillard and Nissen's (2007) findings on the utility of computational modeling research. Dillard and Nissen reveal that while computational experimentation incorporates computer models rather than real people (making it weaker than laboratory experimentation and field methods), it offers distinct benefits to decision-makers.

Primarily, computational modeling allows decision-makers to identify and examine unintended consequences of organizational design changes before actually implementing the design changes. Furthermore, computational organizational modeling provides decision-makers quantitative evidence for enacting prospective design changes within the organization.

The USAF's transformation efforts began at the Air Force Materiel Command's Air Logistics Centers (ALC) (Moseley & Wynne, 2005). The researchers' review of current USAF transformation initiatives did not reveal previous experimentation with computational organizational modeling. Working in concert with other transformation initiatives (i.e., Lean Operations and Six Sigma process improvements), the researchers believe the ALCs are mature "targets of opportunity" to apply computational organizational modeling.

THIS PAGE INTENTIONALLY LEFT BLANK

III. METHODOLOGY

A. INTRODUCTION

This chapter is divided into five sections: an overview of the HV Repair Cell, an outline of the model's characteristics, a description of the model's development, the establishment of the baseline model, and the presentation of seven modeling interventions.

B. DESCRIPTION OF MODELED ORGANIZATION

This section provides an overview of the KC-135 aircraft's Programmed Depot Maintenance (PDM) Flight Controls Repair Cell (also referred to as the HV Repair Cell), its responsibilities, and task breakdowns. The researchers conducted multiple telephone and e-mail exchanges with HV Repair Cell personnel to collect information about the flight controls repair operation in order to build and populate the baseline organizational model. Additionally, the researchers made a site visit to the KC-135 aircraft's PDM Flight Controls Repair Cell, 564th Aircraft Maintenance Squadron (564 AMXS), Oklahoma City Air Logistics Center (OC-ALC) to increase their understanding of the repair and maintenance process and organizational design.

The computational organizational model of the HV Repair Cell includes four repair cell operations. As depicted by Figure 1, the four operations supporting the HV repair process are: production, planning, scheduling, and logistics.

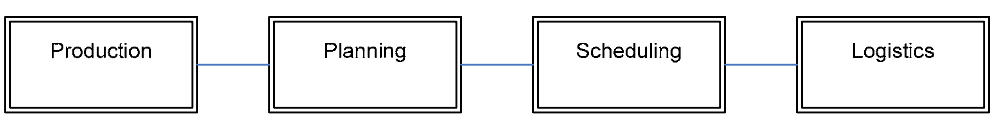


Figure 1. Visual Representation of the HV Repair Cell's Four Sections

1. Production

Production personnel consist of a team leader, nine aircraft mechanics, and 14 sheet metal mechanics. These personnel perform direct repair and maintenance on the

horizontal and vertical stabilizers. After the aircraft's acceptance into the HV Repair Cell, aircraft mechanics remove the elevators, rudder, close-out and balance-bay panels, hinges, linkages, vertical cap fairing, and power control unit (PCU). Following disassembly, production personnel coordinate with the logistics section for necessary repair items and parts. Then, production personnel work with scheduling to route the horizontal stabilizers, vertical stabilizer, balance panels, elevators, and rudder for washing and chemical stripping.

The other removed parts and modules are routed as required. For instance, production personnel place hinges, linkages, and close-out panels on a pallet for storage. The PCU is stored or turned-in as required. Also, personnel route the vertical cap fairing to a supporting back-shop for fiberglass repair.

Following washing and chemical stripping by a supporting back-shop, production personnel perform inspections, coordinate with planning for discrepancy routing, follow-up with logistics for parts and equipment, and begin repairs for lugs, horizontal stabilizers, and the vertical stabilizer.

2. Planning

The planner is responsible for forecasting material to support scheduled HV repairs. The planner uses a 1-year forecast to examine history and determine what percentage of material to order. Additionally, the planner reviews routes, and approves all Air Force Materiel Command (AFMC) Form 202, Nonconforming Technical Assistance Request and Reply forms—used to identify discrepancies outside of technical order repair limits. The planner coordinates with production and may seek assistance from quality control personnel to plan labor requirements and prepare required work control documents (WCDs). Also, the planner coordinates with the logistics section and supporting depot item manager to resolve material-control issues and facilitate parts routing.

3. Scheduling

The Aircraft Logistics Specialist (ALS) is responsible for scheduling, general administration tasks (e.g., preparing the asset's strip package and assembling the aircraft book), updating the Program Depot Maintenance Schedule System (PDMSS), and for updating the Aircraft Parts Tracking System (APTS) according to nomenclature, trailer numbers, storage date, and present location (e.g., an entry of TR135-HV14-SH-3705 in APTS identifies the HV14 assets are located in trailer 135 within building 3705).

4. Logistics

The Forward Logistics Specialist (FLS) is responsible for logistics requirements, such as ordering and tracking material, parts, and equipment. The FLS works with production to control item turn-in and order necessary repair parts if bench stock items are not needed. Otherwise, bench stock items are obtained from supply. The FLS uses the electronic DO43 Master Item Identification Control System to check item Expendability, Recoverability, and Repairability Codes (ERRC) and verify if a repairable part must be turned in for depot-level repair before the FLS ordering a new one. Prior to ordering parts, the FLS researches stock numbers and operation numbers to ensure accuracy. Additionally, if an Industrial Prime Vendor (IPV) item is required by production to accomplish HV repairs, the FLS coordinates with the supporting contractor for the IPV part.

C. MODEL CHARACTERISTICS

This section describes the POWer 3.0a software parameters used to build the KC-135 aircraft's PDM Flight Controls Repair Cell model. The parameters are explained using eProject Management's *SimVision Users' Guide* (2003) and the Collaboratory for Research on Global Projects' POWer Documentation for POWer 2.0 (2006) references.

1. Major Milestones

Milestones identify the objective of the type of work being performed. Within the HV Repair Cell model, a milestone indicates the beginning or end of all work (see Chapter III, Section C.2.) required to complete the milestone's objective.

2. Tasks

After defining the major milestones, the authors define the tasks to accomplish each milestone. Tasks represent all jobs HV Repair Cell employees are responsible for completing. Flight controls maintenance and administrative tasks are described at an effective level-of-detail to keep the model manageable without becoming overly complicated or detailed. Without proper detail, the model does not allow accurate identification of possible alternatives or potential courses of action for enhancing the flight controls PDM process and throughput time. Information within each major task includes:

a. Estimated nominal duration (*effort*) required to complete each task.

b. Estimated skill types and skill-levels (*required skill*) necessary to accomplish each task.

c. Estimated task *priority* and sequencing to identify whether or not tasks are done with a precedence decision, in parallel, or sequentially.

d. Estimated *requirement complexity* to depict how difficult it is for employees to understand task requirements and to represent the number of sub-tasks required to accomplish the overall task.

e. Estimated task *uncertainty* to represent the volume of communication and information-sharing between employees required to perform assigned tasks.

3. Positions

Along with milestones and tasks, positions within the organization that directly impact and complete KC-135 flight controls repair tasks are modeled. Positions include personnel responsible for flight controls repair, administrative paperwork, and

supervising subordinate's efforts and tasks. Additionally, leadership positions modeled depict decision-making personnel who regularly receive questions from subordinates about flight controls maintenance and administrative tasks. Information for each position includes:

a. Number of *full-time equivalent* (FTE) personnel assigned to each position.

b. Specific tasks the position is responsible for completing.

c. Estimated skill-level types (*skill rating*) the position possesses to accomplish each task.

d. Estimated *role* that each position fills to accomplish respective flight controls repair task(s). The POWer Documentation for POWer 2.0 (2006) defines the three roles a position can occupy as Subteam (*st*), Subteam Lead (*sl*), and Project Manager (*pm*).

4. Meetings

In the model, meetings represent important methods whereby personnel in certain positions regularly and reliably transfer information about tasks and repair processes. The organizational model illustrates the types, numbers, and lengths of formal meetings directly affecting the HV repair process. Although personnel attend additional meetings outside of flight controls maintenance, these meetings are not be modeled because it is assumed no information concerning flight controls repair and administration is transferred. This assumption takes a conservative approach. KC-135 aircraft's Flight Controls Repair Cell personnel describe the following meeting characteristics:

a. Regularly scheduled meetings (meeting *interval*, *meeting time*, and *duration*) supporting flight controls repair.

b. Required and optional attendees for regularly scheduled meetings.

c. Other informal meetings/communications supporting flight controls repair.

5. Information Transfer and Decision-making

This section describes decision-making policies and procedures regarding the flight controls repair operation. Parameters stemming from policies impact micro-decision-making behavior of workers and supervisory personnel. For instance, if a responsible decision-maker becomes backlogged during the HV repair process, this may affect positions relying on decision support to complete repair or administrative tasks.

Parameter settings within the HV Repair Model are interrelated and work with other model settings. For example, meetings, rework links, communication links, and exception probability settings interact with *centralization* and *formalization* settings. The model simulates these interactions by predicting project duration, risk, direct and indirect work, functional and project exceptions, cost impacts, position backlog, and functional risk based on the following model parameters:

a. Team Experience. This parameter defines the extent to which organizational members previously and successfully worked together to accomplish the project. The set value determines how quickly or slowly positions process information. Within POWer, *team experience* can be set at high, medium, or low.

b. Centralization. The *centralization* parameter defines whether decisions are made by senior-level positions or decentralized to lower-level (subordinate), responsible positions. The set value establishes how high- or low-level decision-making occurs, which in turn, impacts project duration, position backlog, and project risk. The settings available in POWer for *centralization* include high, medium, and low.

c. Formalization. This parameter defines whether communication within the organization tends to occur formally in meetings, informally between position members, or evenly between formal and informal methods. The set value works closely with the *communication probability* (described below in Chapter III, Section 5.e., Communication Probability) setting by affecting the amount and frequency of coordination across the organization between positions and relating to task completion. This parameter's POWer values consist of high, medium, and low.

d. Matrix Strength. *Matrix strength* defines the "connectedness" of the organization. This setting illustrates the use of informal and formal information exchanges, perceived need to attend meetings, and percentage of formal meetings attended. The set value affects how positions exchange information, in what setting they exchange information, and the frequency of personnel meeting attendance. Within POWer, the *matrix strength* can be set at high, medium, or low. Additionally, according to the *SimVision Users' Guide* (eProjectManagement, 2003):

(1) A high strength value indicates workers focus more on information exchange and have a lower perceived need to attend meetings. At this setting, the POWer simulation calculator makes workers attend 60% of their meetings and take care of 90% of their informal communications.

(2) A medium strength setting means workers make almost even amounts of formal and informal communications. POWer calculates this value so workers attend to 70% of both their informal and formal communications.

(3) A low strength value causes workers to attend more meetings and tend to ignore information exchanges. POWer uses this setting to make workers attend 90% of their meetings and take care of 60% of their informal communications.

e. Communication Probability. Within POWer, this parameter measures the level of communication required between tasks that are interdependent. For instance, if position personnel accomplishing a task must communicate information about work-in-progress to a position responsible for another task, then the two tasks are dependent on information-sharing. The typical value is set in the range of 0.2 to 0.9 (eProjectManagement, 2003). A low value defines jobs involving higher amounts of routine or standardized tasks performed by workers that are more skilled. A high value defines jobs involving other highly-interdependent tasks performed by less skilled or very busy workers.

f. Noise Probability. The *noise probability* parameter measures the probability of interruptions in an ordinary working day that take time away from position members conducting direct flight controls repair tasks. Higher levels of noise within

organizations result in rework and schedule slippages, which then impact position backlog, project risk, cost, and duration. The *SimVision Users' Guide* (eProjectManagement, 2003) references the general POWer noise probability setting in the range of 0.01 (low) to 0.10 (significant, but common). According to the guide, a value of 0.20 or greater generates more rework and increases the organization's likelihood of finishing the project late.

6. Rework Links

Rework links represent where rework occurs resulting from and related to identified tasks. Any rework links added to the model indicate significant exceptions (i.e., unexpected changes or errors) and include a measure of rework duration for the identified dependent tasks. Rework duration is defined as rework *strength* in the model and is discussed in the Model Development section.

There are two model parameters that factor into the simulation (i.e., they take effect) when rework links are added: *Functional Exception Probability* and *Project Exception Probability*.

a. <u>Functional Exception Probability</u>. This parameter defines the probability repair tasks fail due to localized task errors and require rework by the position responsible for the errors. The *SimVision Users' Guide* (eProjectManagment, 2003) explains this parameter is usually set in the range of 0.05 (low) to 0.10 (significant, but common). Higher values for functional exceptions involve unproven technology or innovative work processes. Conversely, lower values involve relatively well-understood technology and standardized work processes.

Errors may be detected through self-check procedures, after completion of related work by position peers, or by a supervisor's review. Position personnel often go up the supervisory chain for assistance for error correction remedies and assistance. When the model generates a functional exception, the *Users' Guide* states the position responsible for correcting the error conducts one of three actions—Rework, Quickfix, or Ignore.

If the supervisor contacted is backlogged and dealing with other issues, workers may ignore or fix errors improperly (quick-fix) to avoid waiting. Ignoring or inadequately fixing errors causes project risk to escalate.

b. Project Exception Probabilities. In POWer, this parameter defines the probability a repair task fails and generates rework for all dependent tasks. If applicable to the organization, these tasks are connected by rework links in the model. The more rework links incorporated into the HV Repair Cell model, the more rework is generated by exceptions that occur. When the model detects a project error, a "project exception" is conveyed to the position accountable for the failed task.

As with functional exceptions, the responsible position reworks, quickly fixes, or ignores the error when the model generates a project exception. Similar to how the model handles functional exceptions with backlogged supervisory positions, if project exceptions are generated and the supervisor responds slowly, workers may decide to ignore or quick-fix and induce higher project risk.

The *SimVision Users' Guide* advises setting the parameter in the range of 0.05 (low) to 0.10 (significant, but common). A low value indicates a project involves relatively standardized tasks and routine processes, while a high value reflects nonstandard and innovative work processes. The guide also states a probability setting of 0.20 or greater can generate so much rework that the project never finishes.

7. Communication Links

Along with rework links, communication links concern tasks requiring technical interdependency, tight coordination, or integration. As stated in Chapter III, Section C.5.e, the *communication probability* parameter measures the level of communication required between interdependent tasks.

As indicated by the POWer Documentation for POWer 2.0 (2006) and *SimVision Users' Guide* (eProjectManagment, 2003), communication links represent task completion and integration dependency. If two tasks require personnel to talk and share information, a communication link is incorporated into the model between those two

interdependent tasks. Communication links inform the model that these tasks depend on each other for information. Additionally, "communication links have no effect on the simulation without rework links" (POWer Documentation for POWer 2.0, 2006, p.21). Thus, wherever a communication link is added, a rework link is also added.

For each communication link, the *task uncertainty* parameter is changed within each interdependent task to account for the amount of information-dependency and communication requirements. According to the *SimVision Users' Guide* (eProjectManagment, 2003), the *task uncertainty* level depends on the degree to which information needed to complete a flight controls repair task is available at the time the task begins. When critical information required for completion is unavailable when a task starts, the uncertainty level is set to high. Conversely, uncertainty level is set to low if most needed information is available at task start time. Examples of information requirements include output from a concurrent task, contingent decisions about task procedures, or unknown conditions surrounding market conditions.

8. Knowledge Links

Knowledge links represent relationships and information-sharing between coworkers. Coworkers provide information to other employees about task requirements by sharing their skills and experiences. Without knowledge-sharing, workers may make decisions concerning task completion that compromise overall task and/or HV repair quality. By sharing information and communicating within the information-hierarchy, functional exceptions and project risk are mitigated.

9. Non-touch Tasks

In addition to modeling core flight controls maintenance and administrative tasks, off-core, non-touch tasks (also known as "dummy tasks") are modeled. These types of tasks reflect the time a position is occupied even when employees assigned to that position are not specifically working core tasks. Non-touch tasks properties and parameters are the same as core repair and administrative tasks.

10. Time Lags

Organizations external to the HV Repair Cell conduct repairs on each set of horizontal and vertical stabilizers. Information regarding outside organizational tasks, work duration, and sequencing is collected. Non-HV Repair Cell tasks are modeled through the use of *time lags* and not stand-alone task boxes. Time delays account for the time HV Repair Cell personnel spend waiting on non-HV Repair Cell functions during the repair cell process flow.

D. MODEL DEVELOPMENT

The following information is used to populate the KC-135 aircraft's PDM Flight Controls Repair Cell model in accordance with the *SimVision Users' Guide* (eProjectManagment, 2003) and the POWer Documentation for POWer 2.0 (2006).

The HV Repair Cell model incorporates the total work effort, which includes: direct work to complete milestones and tasks; repair cell employees accomplishing direct work; meetings workers attend to receive information about repair and administrative procedures; supervision work to handle employees' questions (i.e., exception handling and decision-making); rework between parallel tasks as errors occur; communication work by positions to coordinate interdependent tasks and transfer information; and knowledge-sharing work to represent in-house working relationships.

1. General Model Properties

General model properties are depicted for the overall HV Repair Cell model. Overall program elements define the organization's characteristic, operating environment, and design structure. The general parameters are described within Chapter III, Sections D.6.a. through D.6.f., D.7.a., and D.7b. Program elements include *project* description, *work day*, *work week*, *team experience*, *centralization*, *formalization*, *matrix strength*, *communication probability*, *noise probability*, *functional exception probability*, and *project exception probability* as illustrated by Figure 2.

The HV Repair Cell model's general property panel settings are listed in Appendix A for the initial baseline model and seven intervention models. (Note: *Inst.*

Exception Probability is a new POWer 3.0a software parameter and not defined by the *SimVision Users' Guide* or the POWer Documentation for POWer 2.0. The researchers do not utilize this parameter to construct the HV Repair Cell model).

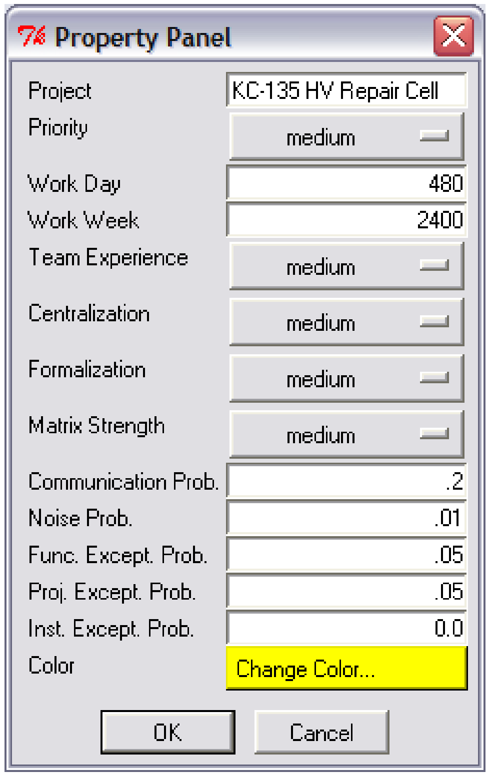


Figure 2. Sample General Property Panel for Initial HV Repair Cell Model

2. Major Milestones

The HV Repair Cell refurbishes the aircraft's vertical and two horizontal stabilizers. Figure 3 depicts the four major milestones within the repair process: acceptance/disassembly, inspection, repair, and buildup.

Figure 3. Horizontal and Vertical Stabilizers Repair Cell Model's Major Milestones

a. Acceptance/Disassembly. The HV repair process begins by inducting the vertical and two horizontal stabilizers into the repair processes. This task is known as acceptance. Acceptance is the responsibility of the repair cell's team leader. It involves individually moving the stabilizers, which are resting on trailers, from the temporary storage area into the repair cell facility. The team leader performs a cursory inspection to identify any potential damage that may have occurred during transport after stabilizers were removed from the aircraft.

Following this brief examination, the stabilizers are disassembled. Disassembly is the responsibility of the HV Repair Cell's aircraft mechanics. After acceptance, the stabilizers are individually hoisted by crane from trailers to work stands for disassembly.

Disassembly involves removing the rudder, leading edge, panels and linkages, closeout panels and balance bay panels from the vertical stabilizer. The elevators, panels and linkages, closeout panels and upper and lower skins are removed from the horizontal stabilizers. The stabilizers are hoisted back onto trailers. Along with the other rudder, elevators, and balance bay panels, the stabilizers are towed from the repair cell to another organization to wash or chemically strip prior to inspection and repair. (Note: the rudder, elevators, and balance bay panels are repaired by a non-HV Repair Cell organization and then returned to the HV Repair Cell for reinstallation on the stabilizers).

b. Inspection. Inspection of the stabilizers is performed by the HV Repair Cell's sheet metal technicians. Inspection requirements include: looking for corrosion, missing items (e.g., bolts), cracks, wear, security, frozen/loose bearings, damage, general condition; delamination of fiberglass assemblies on the vertical stabilizer and of honey comb panels on the horizontal stabilizers; and, checking the integrity of rubber hoses that carry hydraulic fluid, fasteners, antenna area on the vertical stabilizer, vertical and horizontal stabilizer attach points, access panels, lugholes, nut plates, and rubber cables.

All discrepancies are recorded and determined if repair or replacement is needed. Items needing replacement are ordered by the FLS. Any discrepancies outside of technical order repair limits are described and annotated on an AFMC Form 202: Nonconforming Technical Assistance Request and Reply. Then, AFMC Form 202s are submitted to an on-site contractor engineer to determine how to repair the discrepancies.

c. Repair. This milestone includes repair of horizontal and vertical links, horizontal and vertical lugs, and stabilizers. Both types of links are repaired by aircraft mechanics in the same manner. Lugs and stabilizers are repaired by the sheet metal technicians and the team leader. These repairs follow separate repair processes depending on type (e.g., horizontal or vertical). Additionally, some lug repair tasks are performed by non-HV Repair Cell organizations. Outside organizations are dispatched to the flight controls repair facility to perform required lug maintenance.

Throughout the HV repair process, quality-assurance inspections are conducted to monitor and ensure compliance with technical orders and defined task (job) standards.

Ongoing quality inspections are not modeled as separate tasks, but instead included with modeled repair task duration (*effort*) times.

d. Buildup. The buildup process of the horizontal and vertical stabilizers is performed by the cell's aircraft mechanics. By the time this milestone begins, the rudder, elevator, and balance bay panels are delivered and ready for reinstallation on their respective stabilizers.

Buildup requires: general installation; sealing of surfaces; bearing grease and replacement; and installing the links, balance bay panels, rudder, elevator, vertical stabilizer power control unit, and closeout panels. Completion of this milestone is the end of the physical repair process, thus signifying the vertical and horizontal stabilizers are certified complete and ready for reinstallation on the aircraft. The POWer model ends at this milestone.

3. Tasks

During the HV repair process (acceptance/disassembly, inspection, repair, and buildup) simultaneous production, scheduling, planning, and logistics operations occur. The HV Repair Cell model incorporates multiple tasks and sub-tasks taking place by personnel throughout the flight controls repair process.

Figure 4 illustrates the HV Repair Cell Model's four major milestones and horizontal and vertical stabilizers repair tasks. Appendix C lists the baseline HV Repair Cell model's Task Property Panel Settings.

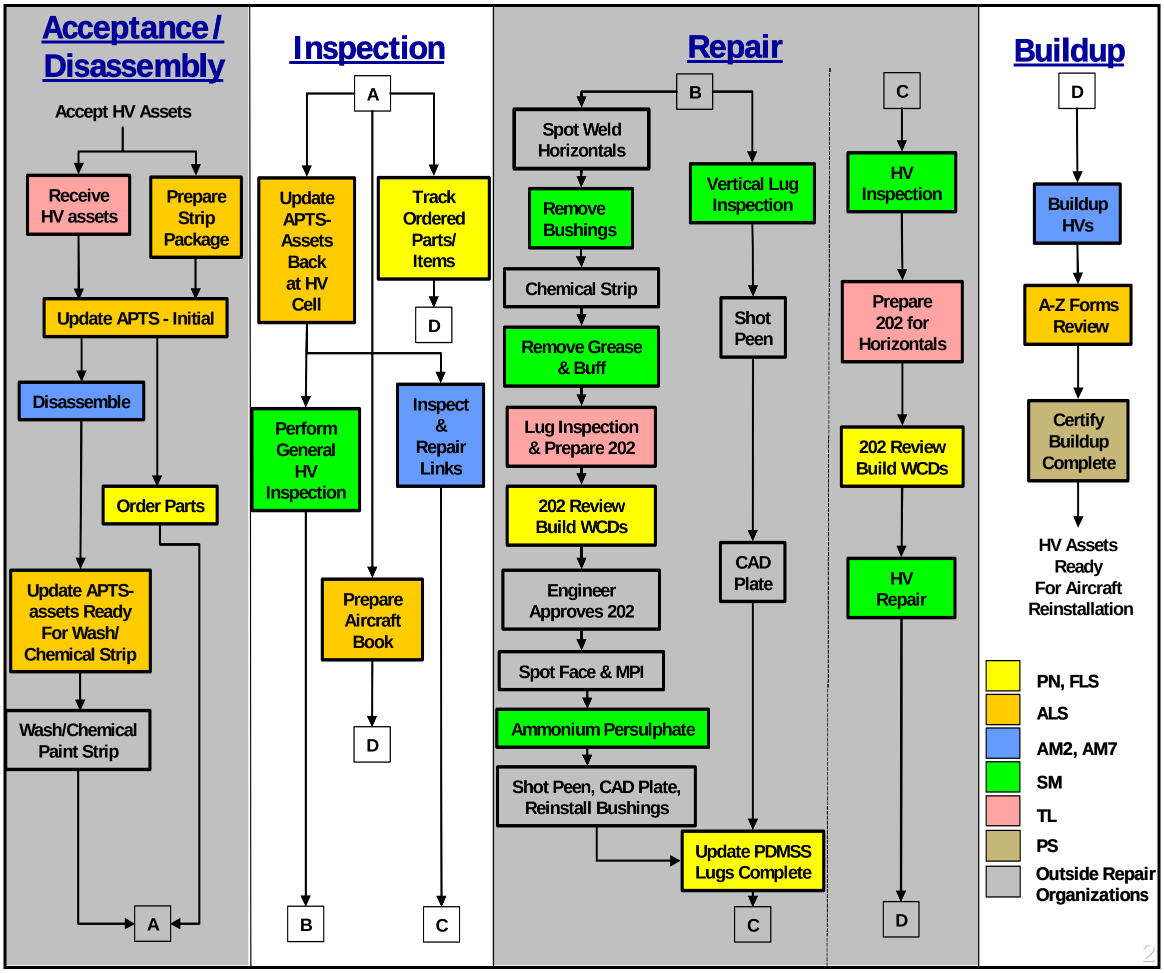


Figure 4. Horizontal and Vertical Stabilizers Repair Cell Model's Milestones and Tasks

Specifically, within the repair milestone, responsible actors perform numerous tasks and sub-tasks as follows:

a. The horizontal stabilizer lug repair includes eleven sequential tasks. Nondestructive Inspection (NDI) technicians from a non-HV Repair Cell organization spot-weld skin splice joints, spars, and surfaces. Sheet metal technicians then remove bushings from lug holes. Next, external wash-rack personnel chemically strip the lug areas. Sheet metal technicians remove grease and buff to remove corrosion before inspection of the lugs. As a certified sheet metal technician, the team lead then inspects

the lugs for serviceability. Based on historical data, AFMC Form 202s are submitted 100% of the time for engineering disposition.

Dispatched machinists spot face to remove corrosion on upper and lower lug holes. NDI personnel perform a magnetic particle inspection of lug surfaces and holes for cracks. Sheet metal technicians apply ammonium persulphate to check for the steel's condition and verify its strength following heat treating of machined surfaces. Wash-rack personnel return to the facility to shot peen all reworked surfaces with steel shot media. Additionally, external cadmium plate technicians brush all cadmium plate steel parts using a low hydrogen embrittlement process. Finally, dispatched machinists install new bushings in the lug holes of the stabilizers to complete the horizontal lug repair process.

b. The vertical stabilizer lug repair includes three sequential tasks. First, sheet metal technicians degrease lug surfaces and remove all primer and surface corrosion. Second, external wash-rack personnel shot peen all reworked surfaces. Finally, cadmium plate technicians brush all cadmium plate steel parts using a low hydrogen embrittlement process.

c. Horizontal and vertical stabilizers are repaired by sheet metal technicians. Following inspection, AFMC Form 202s are required 70% of the time for discrepancies beyond technical order limits. Meanwhile, within-technical-order-limit discrepancies are corrected by technicians. Along with developing the detailed task structure (i.e., sequential and parallel task process flow), other information collected is incorporated into the computational model (as shown by Figure 5 for the "Receipt of Flight Controls" task).

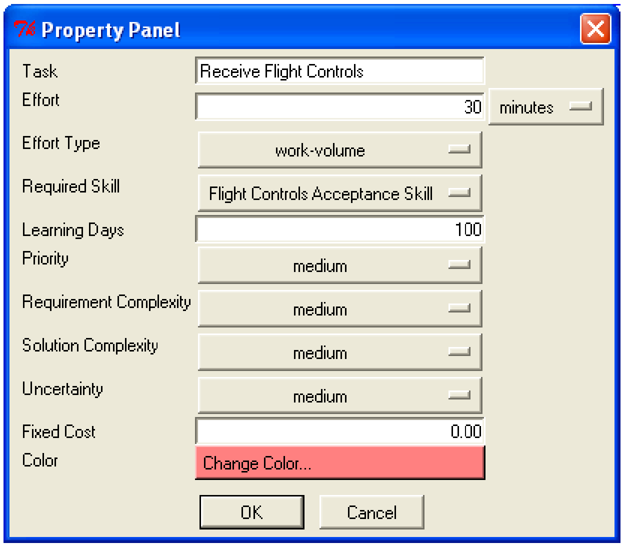


Figure 5. Sample Property Panel for "Receive Flight Controls" Task

Additional task information collected from HV Repair Cell personnel includes:

a. The nominal duration in minutes, represented by *effort* (in Figure 5) required for each task's completion.

b. The determination whether or not each task can be accomplished more quickly if additional personnel are added.

c. The skill types and levels required for each task's accomplishment (represented by the *required skill* parameter in Figure 5).

d. The precedence (*priority*) of each task respective to other tasks for which employees are responsible.

e. The determination of *requirement complexity* for each task to capture how difficult it is for employees to understand task requirements and to represent the number of sub-tasks required to accomplish the overall task.

f. The determination of *uncertainty* for each task to capture the volume of communication and information-sharing between employees required to perform assigned tasks.

4. Positions

Based on knowledge gained from HV Repair Cell interviews and e-mail exchanges, the HV Repair Cell model includes eight positions responsible for executing all repair and administrative tasks and characterizes the hierarchy of information flow among these positions.

Figure 6 depicts the organizational design of the eight positions and information hierarchy. It shows positions executing flight controls repair, accomplishing administrative paperwork, and supervising subordinates' efforts and flight controls repair tasks. The model also includes leadership positions to identify decision-making personnel who regularly receive exception-handling questions from subordinates.

Appendix E identifies the baseline HV Repair Cell model's Position Property Panel Settings.

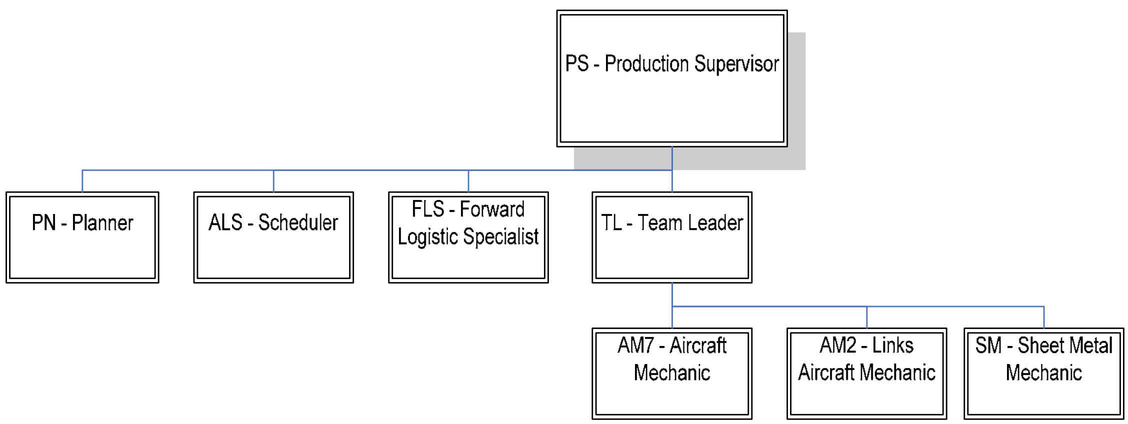


Figure 6. HV Repair Cell Positions and Information Hierarchy

The eight positions in the baseline model include:

a. PS: Production Supervisor, responsible for the overall end-product and that HV repairs are performed and completed properly.

b. TL: Team Leader (illustrated in Figure 7), responsible for HV acceptance, inspections and repairs, and for directing aircraft and sheet metal mechanics.

c. PN: Planner, responsible for forecasting material required for planned HV repairs, reviewing and approving AFMC 202s, and for preparing WCDs.

d. ALS: Aircraft Logistics Specialist, responsible for scheduling, general administration, updating PDMSS, and updating APTS.

e. FLS: Forward Logistics Specialist, responsible for ordering and tracking material requirements.

f. AM7: Seven Aircraft Mechanics that hold high-level repair skills, responsible for disassembly and buildup of horizontal and vertical stabilizers.

g. AM2: Two Aircraft Mechanics that currently hold low-level repair skills, responsible for repairing linkages.

h. SM: 14 Sheet Metal Mechanics, responsible for inspection and repair of lugs, horizontal stabilizers, and vertical stabilizers.

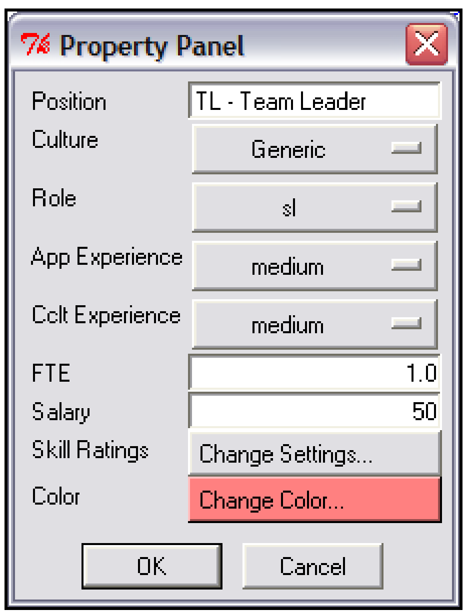


Figure 7. Sample Property Panel for Team Leader Position

For each position, the number of *FTE*s assigned, number of responsible tasks, skill level(s), and roles are developed. Within the supervisory chain and information-

flow hierarchy, higher-level positions (designated by a *pm* or *sl* role assignment) include similar or higher skill levels than the subordinates they supervise and/or handle exceptions. This assigned skill level represents their knowledge, experience, and ability to handle exceptions and communicate information to lower-level positions when required.

For example, Figure 7 illustrates the TL's role is set to *sl* to represent the position's location in the information hierarchy over three *st* positions (AM7, AM2, and SM).

5. Meetings

Meetings represent how positions regularly and reliably transfer information. Only meetings that directly affect flight controls maintenance are modeled. Information describing meeting *priority* compared to other meetings and responsible tasks, meeting *duration*, *intervals* between meetings, and the *meeting time* is entered into the HV Repair Cell model. Figure 8 shows the property panel for the HV Repair Cell's Daily Tail Team Meeting. Additionally, Appendix F lists the baseline HV Repair Cell model's Meeting Property Panel Settings.

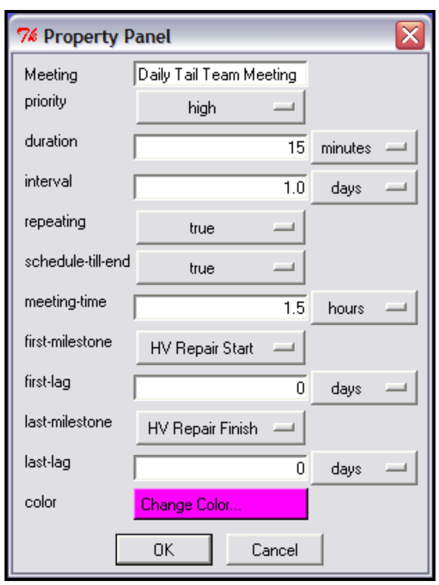


Figure 8. Sample Property Panel for Daily Tail Team Meeting

6. Information Transfer and Decision-making

Based on data collection and communications with HV Repair Cell personnel, the researchers describe the decision-making policies and procedures regarding flight controls repair in this section. These parameters are set on the General Property Repair Panel (refer to Appendix A and Chapter III, Section D.1.).

a. Team Experience. Chapter III, Section C.5.a. (above) defines *team experience* as the extent to which organizational members previously and successfully worked together to accomplish the project. POWer allows the modeler to select a high, medium, or low setting. Interviews and personal observation substantiate the organization has previous experience completing KC-135 flight controls repairs. However, based on information provided by HV Repair Cell leaders, six of 29 (20.7%) employees are new hires; they entered the organization over the last six months.

Four sheet metal mechanics experienced at performing other KC-135 PDM repairs are now learning the horizontal and vertical stabilizer repair process. Additionally, two inexperienced sheet metal apprentices are starting to learn how to repair stabilizers. New personnel impact the organization by requiring all personnel to increase the amount and time spent on information-sharing. Therefore, the *team experience* parameter is initially set to medium.

b. Centralization. Chapter III, Section C.5.b. above describes *centralization* as the metric depicting whether organizational decisions are made by senior-level positions or are decentralized to lower-level (subordinate) responsible positions. The settings for this parameter are high, medium, or low.

Collected information describes decision-making responsibilities within the repair cell. Accordingly, the majority of repair and administrative tasks are routine. Decision-making responsibility is primarily decentralized at positions with *st* roles (i.e., the ALS, PN, FLS, AM7, AM2, and SM positions). On the other hand, critical decisions and exception-handling involving less standardized tasks are retained by higher-level management personnel. For example, during removal of lug bushings when extensive corrosion is encountered, Sheet Metal Mechanics require the team leader's involvement

to decide how to continue removing bushings. Overall, within the flight controls repair cell, *centralization* for the baseline is modeled as medium.

c. <u>Formalization</u>. Chapter III, Section C.5.c. explains *formalization* is the parameter to describe whether communication methods tend to occur formally in meetings, informally between position members, or evenly between formal and informal methods. In the model, the parameter may have a high, medium, or low setting. Collected information confirms most communication occurs evenly between formal meetings and informally between positions. Therefore, *formalization* is initially set to medium.

d. <u>Matrix Strength</u>. As discussed previously in Chapter III, Section C.5.d., the model's *matrix strength* setting (high, medium, or low) represents the amount of informal and formal information exchanges between workers and how workers perceive necessary meeting attendance. *Matrix strength* also measures the percentage of formal meetings attended. Each strength setting has corresponding probability values calculated during a simulation run.

Interviews with HV Repair Cell personnel and observation of operations reveal informal and formal information exchanges occur routinely and evenly. On average, organizational personnel attend all required meetings and communicate informally to learn about task completion. Therefore, based on the information collected and compared with the definitions and effects of the strength settings, the baseline model's *matrix strength* value is set to medium.

e. <u>Communication Probability</u>. In Chapter III, Section C.5.e., this parameter is defined as the level of communication required between tasks that are independent and typically set with a POWer value from 0.2 to 0.9. Interviews with organizational personnel and observations made during the site visit provided the researchers with the basis for identifying HV maintenance and administrative tasks as highly standardized and routine. Additionally, the HV repair process and tasks are performed by skilled employees.

Based on interview and observational data assessment, the parameter definition, and understanding of its effect on the simulation, an initial *communication probability* value of 0.2 seems appropriate. This setting means that, on average, there is a 20% chance a worker will need to communicate something about the task-in-progress with the position responsible for the linked task.

f. Noise Probability. Chapter III, Section C.5.f. above defines this parameter as the probability interruptions in an ordinary working day will take time away from HV Repair Cell employees conducting flight controls repair and administrative tasks. POWer uses values ranging from 0.01 (low) to 1.0 (significant, but common) to represent *noise probability*.

During interviews, personnel explained they experienced few, if any, interruptions because of limited exposure to interruption requests. There are no additional duty assignments outside the HV Repair Cell. Observations of the working environment reveal the cell is located separately from other organizations. Their secluded location helps minimize worker disruptions. Interviews and observation analysis support the conclusion that *noise probability* is extremely low, which corresponds to a 0.01 POWer setting.

7. Rework Links

Collected information demonstrates rework within the flight controls repair process seldom occurs. HV Repair Cell leaders attribute infrequent rework to task repetition and standardization, learning-curve effects, and personnel's high skill levels. While rework is rarely necessary, four rework links are included in the model to represent the impact between interdependent tasks when rework is required. Appendix G identifies the baseline HV Repair Cell model's Rework Link Property Panel Settings.

For example, there is a rework link between the driver ("upstream") task Buildup of Horizontal Stabilizers (Buildup-H) and the dependent task Average Repair of Horizontal Stabilizers (Average Repair-H). The initial rework *strength* associated with this dependent task is 0.3% as shown in Figure 9.

The 0.3% value indicates that if a project exception occurs within the Buildup-H task, which causes rework, 0.3% of the Average Repair-H task (duration: 19,674 minutes x 0.3% = 60 minutes) will be added to the project duration on average. This additional time is consistent with information supplied by repair cell personnel.

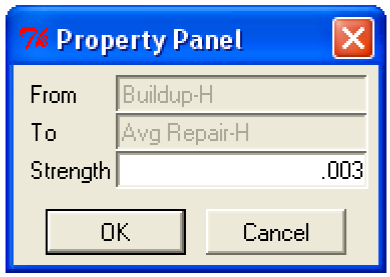


Figure 9. Sample Property Panel for Rework Link

The following two parameters illustrate how the repair cell handles significant exceptions during the flight controls repair process.

a. <u>Functional Exception Probabilities</u>. As discussed previously in Chapter III, Section C.6.a., this parameter describes the probability repair tasks fail due to localized task errors and require rework by the position responsible for completing the task. POWer measures this parameter based on values from 0.05 (low) to 0.10 (significant, but common). Interviews and observations validate flight controls repair involves well-understood technology, established technical orders, and standardized work processes. Data supports the assessment *functional exception probability* is extremely low; therefore, the value is set to 0.05 for the baseline model.

b. <u>Project Exception Probabilities</u>. Chapter III, Section C.6.b. explains this parameter is the probability repair tasks will fail and generate rework for dependent tasks connected by the rework links within the model. POWer employs the probability setting—typically a value between 0.05 (low) and 0.10 (significant, but common)—during the simulation to generate project exceptions. Information collected supports the determination that HV Repair Cell repair and administrative tasks entail routine work-processes. Thus, the baseline *project exception probability* value is set to 0.05.

8. Communication Links

Collected information defines technically interdependent and tightly coordinated tasks. Along with the four rework links, there are four communication links included in the model to represent highly integrated tasks requiring information-sharing between positions. Appendix H lists the baseline HV Repair Cell model's Communication Link Property Panel Settings.

For example, there is a communication link between the Buildup-H task and the Average Repair-H task. This ensures aircraft mechanics and sheet metal mechanics responsible for completing these two tasks share information about their respective tasks. Furthermore, the *task uncertainty* parameter for this communication link is set to low in accordance with the *SimVision Users' Guide* (eProjectManagement, 2003). Since HV repair procedures are highly standardized, most information required to complete Buildup-H is available when the task begins. On average, a low-level of communication exchanges occurs between position personnel if rework is required on a task.

9. Knowledge Links

Through interviews and personal observation, the researchers found that close working relationships exist between repair and administrative personnel. For instance, mechanics often ask skill-level questions of the experienced team leader. Another key example is the close working relationship between the team leader and planner while they accomplish AFMC Form 202 and Work Control Document tasks.

Seven knowledge links are included in the model to represent knowledge-sharing among repair cell employees. Appendix I depicts the baseline HV Repair Cell model's Knowledge Link Property Panel Settings.

As an example, the property panel and skill-rating panel shown in Figure 10 describe the knowledge link between sheet metal mechanics and the team leader. To answer and resolve SM position inquiries, the TL position has a designated "Sheet Metal Mechanic Skills" *skill-rating*. In the model, the TL's *skill-rating* parameter is set to high. This setting reflects the level of sheet metal skills the SM position perceives the TL position to possess.

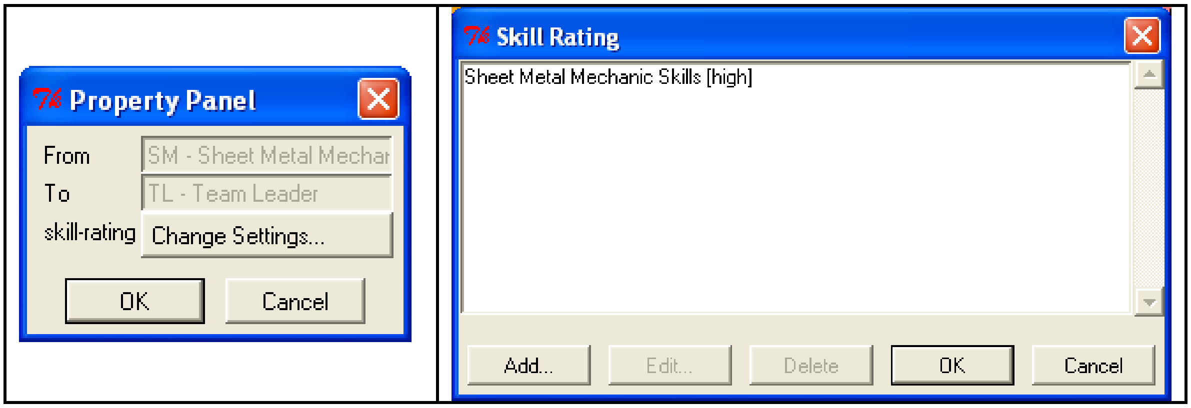


Figure 10. Sample Property Panel and Skill-rating Panel for SM to TL Knowledge Link

10. Non-touch Tasks

Along with modeling core flight controls maintenance tasks, the model analyzes off-core, non-touch tasks to ensure positions are occupied during the entire HV Repair Cell process. The HV Repair Cell model includes eight non-touch tasks. Non-touch tasks indicate periods when flight controls personnel are conducting other-than-principal repair and administrative tasks. The model's non-touch tasks settings are listed in Appendix C, Task Property Panel Settings.

For instance, for the "ALS' Non-touch Tasks" task, the *effort* parameter is set to 60 minutes/day x 3 days/week x 7 weeks = 1260 minutes. This duration captures when the ALS position is occupied and not specifically working on a core HV Repair Cell task. The 1260 minutes represents the time provided to employees for conducting physical fitness through the "Fit for Fight" program. The 1260 minutes accounts for three 60-minute sessions per week for the duration of the HV stabilizer repair of 7 weeks. Additionally, the *priority* parameter for each non-touch task is set to low (except for the "PS's Non-touch Tasks" discussed in the next paragraph) because all "core" flight controls repair tasks take precedence over non-touch tasks.

The production supervisor's (PS) non-touch task has a *priority* parameter set to high. The PS position's duties primarily entail administrative and supervisory responsibilities and consist of assigning daily repair tasks, preparing for daily events,

monitoring personnel actions, intra-organization coordination, personnel training, and special projects. The only core ("touch") task included in the model for the PS is the "Certify Buildup Complete" task, which also has a *priority* parameter set to high.

The "PS's Non-touch Tasks" *effort* parameter is set to 430 minutes. These 430 minutes are calculated by taking the time the PS position spends during a daily 8-hour shift and subtracting the time the PS spends at three daily meetings (Roll Call, HV Turnover, and Daily Tail Team):

430 min = 480 min - [15-min Roll Call] - [20-min Turnover] - [15-min Daily Tail Team]

Moreover, the "PS's Non-touch Tasks" *effort* setting ensures the model completes this task early in the repair process to not interfere with other tasks along the critical milestone path. The PS position's non-touch task responsibilities are important to the HV Repair Cell's daily operations and functionality because they indirectly affect all core flight controls repair and administrative tasks.

11. Time Lags

The model represents repair of one set of horizontal and vertical stabilizers. Both non-HV Repair Cells (e.g., wash/chemical strip personnel and engineers) and the HV Repair Cell perform direct work on all sets. Non-HV Repair Cell tasks are modeled through the use of *time lags* and not through the use of separate task boxes. Time delays account for time HV Repair Cell personnel spend waiting on non-HV Repair Cell maintenance functions. Since HV Repair Cell personnel can work on up to six sets at once, they perform tasks on other stabilizers while non-HV repairs are conducted.

With respect to this modeling effort, the researchers determined organizational interventions would only be applied to internal HV Repair Cell functions. This research focuses only on direct and indirect work (i.e., coordination time, supervision time, rework time, and waiting time) of HV Repair Cell personnel performing flight controls repair and administrative tasks.

For example, Figure 11 depicts a *time lag* of 492 minutes between the "Update PDMSS—Lug Priorities" task and the "Remove Bushings" task. This duration accounts

for the average time that Nondestructive Inspection Technicians perform spot welds on skin splice joints, spars, and surfaces during the repair of horizontal stabilizer lugs.

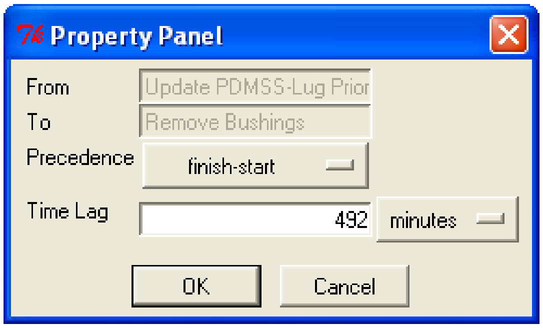


Figure 11. Sample Property Panel to Account for Time Lag between Update PDMSS—Lug Priorities and Remove Bushings Tasks

For AFMC Form 202s, engineers take an average of seven days to complete review and provide repair solutions. However, because HV Repair Cell personnel are never idle, this 7-day delay to account for engineer duration is not included in the model.

Appendix D identifies seven time lag property panels to represent time delays performed by outside repair organizations

E. BASELINE MODEL

The computational organizational model of the flight controls repair operation emulates the HV Repair Cell's current process and operations. Figure 12 depicts a screenshot of the HV Repair Cell baseline model. Within the screenshot, the three parallelograms at the top represent meetings, the eight "people" objects represent positions, the rectangles below the eight positions represent core "touch" tasks, the hexagons represent completion milestones, and the long rectangles to the upper right represent non-touch tasks.

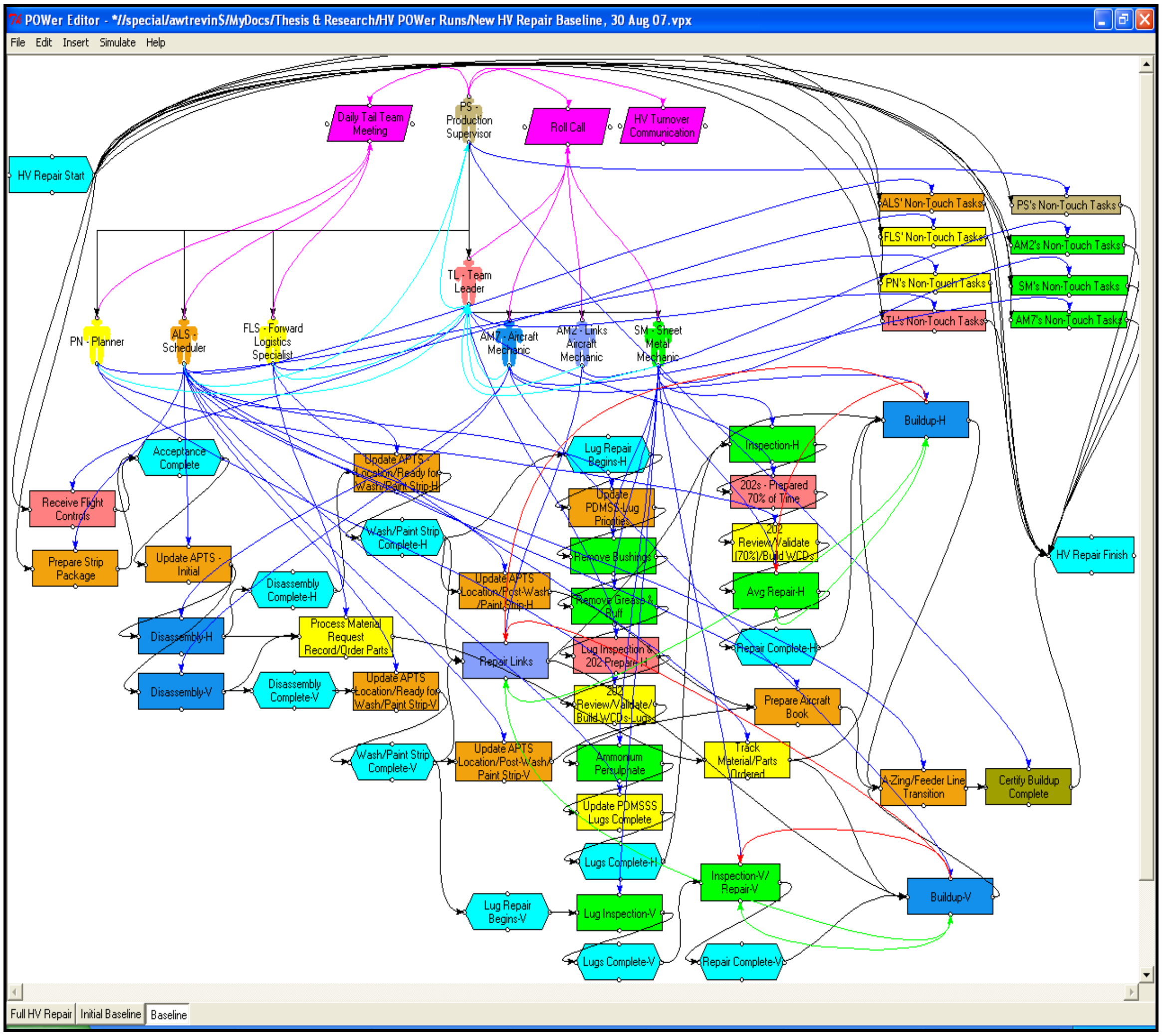


Figure 12. Screenshot of HV Repair Cell Baseline Model

In the HV Repair Cell Model, positions and assigned tasks are color-coded with the same color. Positions connect to assigned tasks using blue task-assignment arrows. The black arrows connecting positions to positions from the "head" represent supervisory roles. The light-blue arrows connecting positions to positions from the "feet" represent knowledge links. The pink arrows connecting positions to meetings represent required meeting attendance. While difficult to see in the figure, four sets of arrows between tasks represent rework (red arrows) and communication links (green arrows). Finally, the black arrows that link each task (rectangle) and milestone (hexagon), starting from the

HV Repair Start milestone, and ending with the HV Repair Finish milestone, represent sequential and parallel tasks within the HV Repair Cell process flow path.

The validity of the baseline model's output is critical to accurately gauging the effects of changes (interventions) made to the baseline. Sensitivity analysis increases confidence in the baseline model's validity. The researchers reviewed the Property Panel parameters (Chapter III, Section D.1.) to determine which value settings could be changed, but still emulate the actual HV Repair Cell based on interviews, observations, data, and recommended SimVision guidelines.

The *communication probability* parameter is selected as the ideal parameter to modify in order for researchers to assess impacts to the HV Repair Cell Model. According to the *SimVision Users' Guide* (eProjectManagement, 2003), this value is normally set in the range of 0.2 to 0.9. As stated in Chapter III, Section D.6.e., the initial baseline's *communication probability* setting is 0.2. To conduct the sensitivity analysis, the parameter is first lowered to 0.1 and then increased to 0.3.

Table 1 illustrates the results of the sensitivity analysis. After running each simulation, the researchers compared project duration output to the original baseline model's project duration and the historical data provided. According to the HV Repair Cell, average repairs take 35 days. The baseline's duration of 34.32 days provides the closest approximate result—within 1.9% of the historical 35-day turnaround time. Changing the *communication probability* setting to 0.1 or 0.3 reduces project duration by 0.10% and 0.19% from the baseline's prediction, to 34.29 and 34.26 days respectively. Thus, the baseline model best emulates the actual HV repair process.

Sensitivity Analysis	Baseline Model	Sensitivity Analysis	% Change	Sensitivity Analysis	% Change
	Starting Point	Lowered Comm Prob from .2 to .1		Increased Comm Prob from .2 to .3	
Simulated Project Duration (days)	34.32	34.29	-0.10%	34.26	-0.19%
Direct Work Time (days)	130.52	130.52	NO CHANGE	130.52	NO CHANGE
Indirect (Hidden) Work Time (days):	30.85	29.72	-3.66%	31.46	1.96%
Rework Time (days)	*5.03*	*5.25*	*4.42%*	*4.84*	*-3.85%*
Coordination Time (days)	*18.31*	*17.02*	*-7.03%*	*19.48*	*6.39%*
Exception-Handling Wait Time (days)	*7.51*	*7.45*	*-0.88%*	*7.15*	*-4.91%*
Total Direct & Indirect (Hidden) Time (days)	161.38	160.25	-0.70%	161.98	0.38%
Total Project Cost ($)	$60,627.98	$59,811.04	-1.35%	$61,231.14	0.99%
Total Functional & Project Exception Time (days):	8.74	8.89	1.82%	8.51	-2.60%
Functional Exception Work (days)	*7.95*	*7.99*	*0.44%*	*7.74*	*-2.72%*
Project Exception Work (days)	*0.77*	*0.90*	*15.81%*	*0.76*	*-1.36%*
Project Risk	0.07	0.08	14.71%	0.07	NO CHANGE
Position Backlog (days)	2.87	2.84	-0.92%	2.88	0.34%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	NO CHANGE	AM2—Links Aircraft Mechanic	NO CHANGE

Table 1. Sensitivity Analysis for Communication Probability Parameter

The flight controls repair duration predicted by the model sufficiently reflects the real-world duration of 35 calendar days provided by HV Repair Cell personnel. The accuracy and consistency of the model improves the probability that running the simulation predicts realistic outputs. Therefore, the HV Repair Cell model can be used to forecast performance outputs regarding flight controls repair duration, direct and indirect/hidden work, project cost and risk, and exception-handling.

Running the baseline model helps the model's operator identify potential problem areas. Examples of problem areas include: hotspot areas, position and task backlog, unrealistic or hard-to-achieve schedules, and increased project duration or risk. Hotspot areas may increase project duration and/or project risk. Positions may experience backlog resulting from: task buildup, large durations of direct work, time spent coordinating interdependent tasks, time spent answering questions from subordinates needing problem-resolution or task-completion assistance, and time spent attending project meetings. Because communication quality risks are correlated with project failure, tasks with a higher potential for low-quality work-related communications may become critical issues and harder for leaders to correct later.

Additionally, position and task backlog may cause project bottlenecks and increase decision waiting time, which ultimately affects project risk. For example, the HV Repair Cell model predicts whether or not aircraft or sheet metal mechanics are impacted if the team leader becomes backlogged. The model highlights this "domino effect" by portraying tasks and positions compelled to wait by other backlogged actors. Backlogged personnel may lose valuable time trying to catch up with their work, miss coordinating with interdependent colleagues, or fail to attend important meetings.

The model may also be used to identify organizational design parameters that negatively impact project and functional exceptions and/or increase project risk. Certain tasks trigger the need for higher coordination or information-sharing and influence the model's output (e.g., rework and coordination output statistics). The model's output facilitates development of organizational design interventions (alternative "what if" scenarios) to shorten repair throughput time and positively impact the repair process. The researchers have modified the baseline model to examine the implications of designed interventions on reducing flight controls repair cycle time, risk, and cost.

After establishing the baseline model, the researchers simulated execution of flight controls repair to assess realistic delays and process risks associated with the projected organizational design. In addition, in order for HV Repair Cell leaders to reduce the impact of potential problem areas, this research identified feasible organization and work process modifications that meet acceptable quality and risk tradeoffs.

F. INTERVENTIONS

Once the model is determined to accurately depict current flight controls repair operations, the researchers developed interventions to modify the model and evaluate organizational design alternatives. The model simulates specific interventions to predict effects on performance and likelihood of success. Table 2 depicts the eight output parameters evaluated during this research, including: simulated project duration; direct work time; indirect (hidden) time measured by rework time, coordination time, exception-handling wait time; total direct and indirect work time; total project cost; total

functional and project exception time measured by functional exception work and project exception work; project risk; and position backlog. The output parameters are explained in Chapter IV, Section C.

Numerical Output	Baseline Model Starting Point
Simulated Project Duration (days)	34.32
Direct Work Time (days)	130.52
Indirect (Hidden) Work Time (days):	30.85
Rework Time (days)	*5.03*
Coordination Time (days)	*18.31*
Exception-Handling Wait Time (days)	*7.51*
Total Direct & Indirect (Hidden) Time (days)	161.38
Total Project Cost ($)	$60,627.98
Total Functional & Project Exception Time (days)	8.74
Functional Exception Work (days)	*7.95*
Project Exception Work (days)	*0.77*
Project Risk	0.07
Position Backlog (days)	2.87
Position With Highest Backlog	AM2—Links Aircraft Mechanic

Table 2. Sample Output Parameters, HV Repair Cell Baseline Model

Seven interventions are applied to the baseline model, including:

1. Adding a sheet metal mechanic to the current pool of 14 sheet metal mechanics.

2. Combining the AM2 position and AM7 position to create one pool of nine aircraft mechanics called the AM9 position.

3. Changing the level of *centralization* from medium to low.

4. Increasing the *functional exception probability* parameter value from 5% to 10%.

5. Combining Intervention 2 (create AM9 position) and Intervention 3 (change *centralization* to low).

6. Cross-training and combining all aircraft and sheet metal mechanics to create one mechanic position called "Mechanic Pool."

7. Changing the following parameters to analyze the expected output if three unit personnel retire within the next two fiscal years (FY08-FY10): *team experience*, *communication probability*, *project exception probability*, and *functional exception probability*.

Simulating different interventions of the baseline HV Repair Cell model allows the researchers to quantify the impact to organizational time, cost, and risk. Previewing potential organizational changes and subsequent impacts before expending resources is a valuable cost-effective advantage. Furthermore, the model provides flight controls' decision-makers quantitative evidence for enacting prospective design modifications within the organization.

1. Intervention 1—Employ One Additional Sheet Metal Mechanic

The time (*effort*) spent on sheet metal mechanics' tasks is longer than the time spent on aircraft mechanic tasks (which include only the disassembly and buildup tasks). By adding an additional sheet metal mechanic to the current pool of 14 sheet metal mechanics, overall project duration is predicted to decrease, while project cost (reflecting an added HV Repair Cell employee) is predicted to increase. This intervention provides insight into how much the duration to repair the stabilizers could be reduced after the quantity of sheet metal mechanics responsible for repairs is increased.

2. Intervention 2—Combine AM2/AM7 Positions, Create AM9 Position

Currently, the nine aircraft mechanics are divided into two positions responsible for different tasks: two mechanics (AM2) that only repair linkages and seven mechanics (AM7) that perform all disassembly and buildup tasks. Although the AM2 and AM7 positions possess the same aircraft mechanic job-series, the AM2 position is separated to match overall skill-level to the "Repair Links" task's required low skill-level. The

baseline model (Figure 6) contains separate positions for high-level-skilled AM7 mechanics and low-level-skilled AM2 mechanics. This division of labor creates two different types of workers with different qualifications. Figure 13 illustrates the HV Repair Cell positions and information hierarchy after Intervention 2 is implemented.

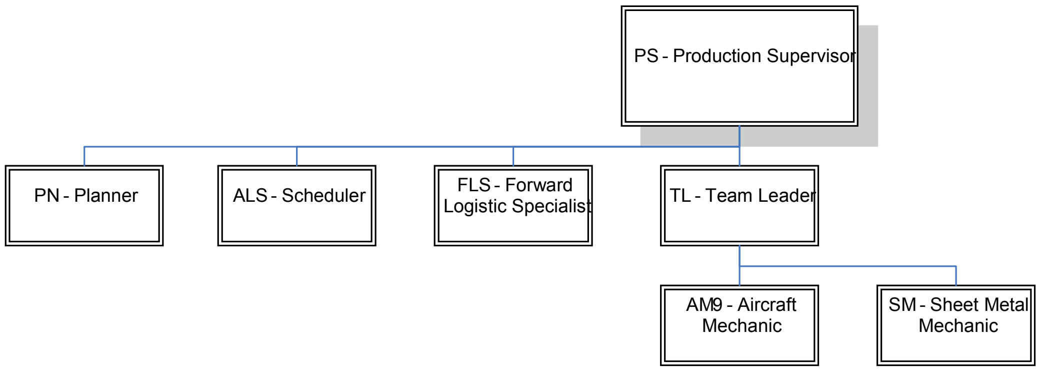


Figure 13. Intervention 2, HV Repair Cell Positions and Information Hierarchy

For this intervention, AM2 and AM7 positions are combined to simulate an HV Repair Cell with a pool of aircraft mechanics in the "AM9" position. This modification merges AM2 and AM7 personnel—allowing one AM9 position to perform all aircraft mechanic tasks previously assigned to the separate positions.

For example, the AM9 position becomes responsible for the "Inspect and Repair Links" task instead of the AM2 position. Figure 14 depicts apportioned tasks (boxes are shaded blue) for the restructured AM9 position: Disassemble, Inspect and Repair Links, and Buildup HVs.

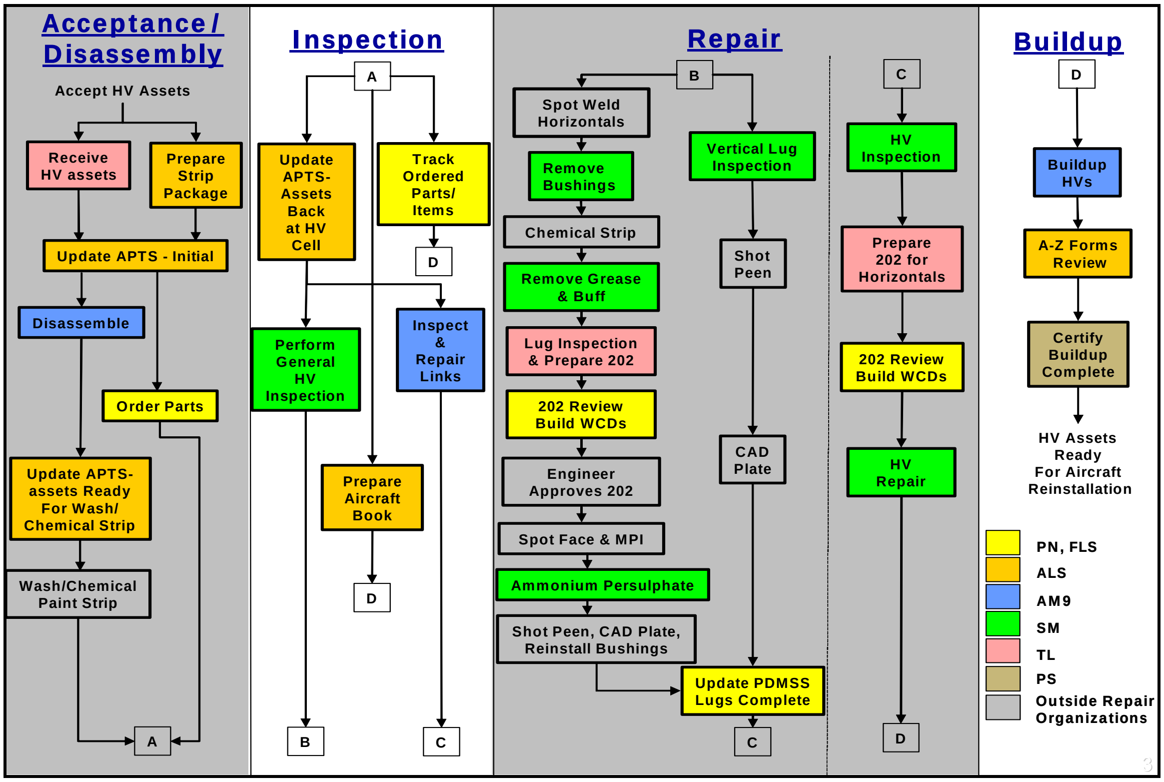


Figure 14. Intervention 2, Horizontal and Vertical Stabilizers Repair Cell Model's Milestones and Tasks

The intervention is simulated twice (represented by Intervention 2a and Intervention 2b). To allow learning-curve effects to occur over time (short-term versus long-term), the researchers run the intervention model first with the AM9 position's Aircraft Mechanic Skills setting at medium (Intervention 2a) and then with the AM9 position's Aircraft Mechanic Skills setting at high (Intervention 2b). By comparing the output of these two interventions, the results reflect time and effort involved to integrate the AM2 and AM7 positions. The second intervention run with high Aircraft Mechanic Skills is expected to demonstrate steady-state effects of the learning curve.

This intervention is projected to show the impact of knowledge-sharing and enhanced training of low-level-skilled personnel (assigned to the former AM2 position) on the HV repair process. These improvements are expected to reduce overall project duration and decrease rework time. Since the intervention entails learning-curve effects, the model may at first exhibit an increase in coordination wait time and exception-handling wait time as AM2 members learn new tasks and ask more questions.

3. Intervention 3—Change *Centralization* from Medium to Low

The baseline model's *centralization* parameter is set to medium (discussed in Chapter III, Sections C.5.b. and D.6.b.) as a result of assessing the organization's current decision-making and exception-handling responsibilities. The *centralization* parameter for Intervention 3 is set to low. Appendix A depicts the general property panel settings for Intervention 3.

This intervention lowers the level of *centralization* from medium to low, thereby changing the organization's decision-making practices to a decentralized operation. The results of this intervention are expected to simulate low levels of centralization by decreasing overall repair time, rework, coordination, and exception-handling wait time. Yet, low levels of centralization are also expected to increase project risk as HV Repair Cell employees seek less information from higher-level decision-makers.

4. Intervention 4—Increase *Functional Exception Probability* to 10%

The current stabilizers' repair process is routine and standardized. This intervention evaluates the effects of added stress if the HV stabilizer repair process becomes less standardized and causes more *exceptions*. Appendix A illustrates the general property panel settings for Intervention 4.

Recently, stabilizers from KC-135s (undergoing PDM) assigned to units in highly corrosive environments (e.g., Kadena Air Base, Japan) have displayed more severe corrosion damage than previously experienced. This damage impacts repair diagnosis and repair time by causing more exceptions during the repair process. Thus, mechanics and administrators make more exception-handling inquiries to the team leader on how to proceed. Additionally, the probability repair tasks fail and require rework due to errors increases because removing corrosion involves less standardized work procedures.

The results of this intervention are expected to show the impact when high corrosion becomes a more typical diagnosis during the HV repair process. As high corrosion becomes the norm, repair guidance will need updating to reflect new diagnosis procedures. Introducing updated guidance will change the current routine repair process by adding non-standardized tasks.

As mechanics and administrators learn the new procedures, more functional exceptions are predicted to occur. To model the added stress to the system, the *functional exception probability* parameter value is increased from 5% to 10%. Overall project duration, project cost, and project risk are predicted to increase as the HV Repair Cell learns and struggles through new operating procedures. As strain on the flight controls system increases, the amount of exceptions are expected to increase considerably.

5. Intervention 5—Combine Intervention 2b and Intervention 3

After evaluating the simulation results of the first four interventions, the researchers develop a combined intervention to assess potential synergistic effects. This intervention should reveal whether beneficial interventions executed in isolation result in the same or continued improvement when integrated. Appendix A identifies the general property panel settings for Intervention 5.

Intervention 2b (Create AM9 Position with high skills) and Intervention 3 (Change *Centralization* from Medium to Low) are combined, as they are the least complicated and most economical organizational design changes suggested. Lowering the number of HV Repair Cell positions may increase the risk of task completion, but should not require extensive financial resources.

Once all aircraft mechanics attain a high skill level, HV repair process duration and risk are expected to decrease. Decentralizing decision-making responsibility to the individual worker level presumes a commitment to empowering subordinates, but not increased funding. To model this intervention, the researchers combine the AM7 and AM2 positions into one AM9 position with a high Aircraft Mechanics Skill setting, and they set the model's *centralization* parameter to low.

Figure 13 illustrates the HV Repair Cell positions and information hierarchy after Intervention 5 is implemented (Note: the positions and information hierarchy for Intervention 2 and Intervention 5 are identical). Project duration, rework time, and cost are predicted to decrease, while project risk is predicted to increase.

6. Intervention 6—Cross-train and Create One Mechanic Pool Position

According to the production supervisor, current OC-ALC hiring and operating regulations prohibit employees from formal cross-training. If cross-training is not permitted by the collective bargaining agreement (CBA) negotiated between OC-ALC and union representatives, mechanics cannot be formally trained outside the job series (i.e., aircraft, sheet metal, electric, or avionics) they were hired to perform.

The US Office of Personnel Management's (OPM) website (2007) provides information about the federal classification and job-grading system. Typically, in order for personnel to capture cross-training among different job-series positions, the job series' description should be modified. Presently, aircraft mechanics that conduct some duties or responsibilities of the sheet metal mechanic job series cannot receive formal credit for performing sheet metal work or be reclassified. According to the OPM, in order for a federal employee to be reclassified into a new series, the work he/she performs must reflect the job series' occupational definition entirely and not just portions of that occupation's duties and responsibilities.

Internally, the HV Repair Cell cross-trains personnel; however, personnel do not receive official credit (documented in personal records) for training outside their current job series. While current rules prohibit formal credit, this intervention evaluates the impact if the OC-ALC CBA is renegotiated to allow formal cross-training in the future. Figure 15 portrays the HV Repair Cell's positions and information hierarchy after Intervention 6 is modeled.

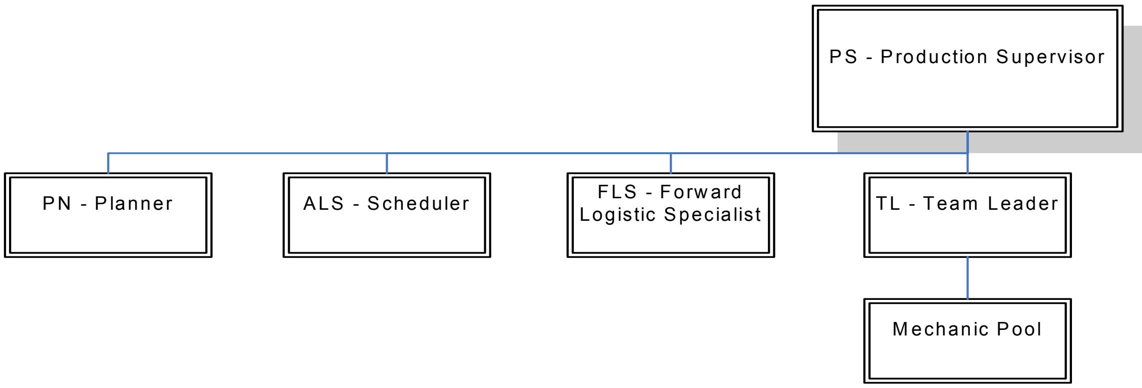


Figure 15. Intervention 6, HV Repair Cell's Positions and Information Hierarchy

To simulate the results of cross-training aircraft and sheet metal mechanics, the researchers create one mechanic resource pool (called the Mechanic Pool position) with an *FTE* of 23 workers (14 SM workers + 2 AM2 workers + 7 AM7 workers).

Figure 16 depicts new HV tasks apportioned to the restructured Mechanic Pool position. The updated apportioned tasks for the Mechanic Pool position include: disassembly, general HV inspection, inspection and repair of linkages, removal of bushings, grease and buff lugs, ammonium persulphate, inspection of vertical lugs, HV repair, and HV buildup.

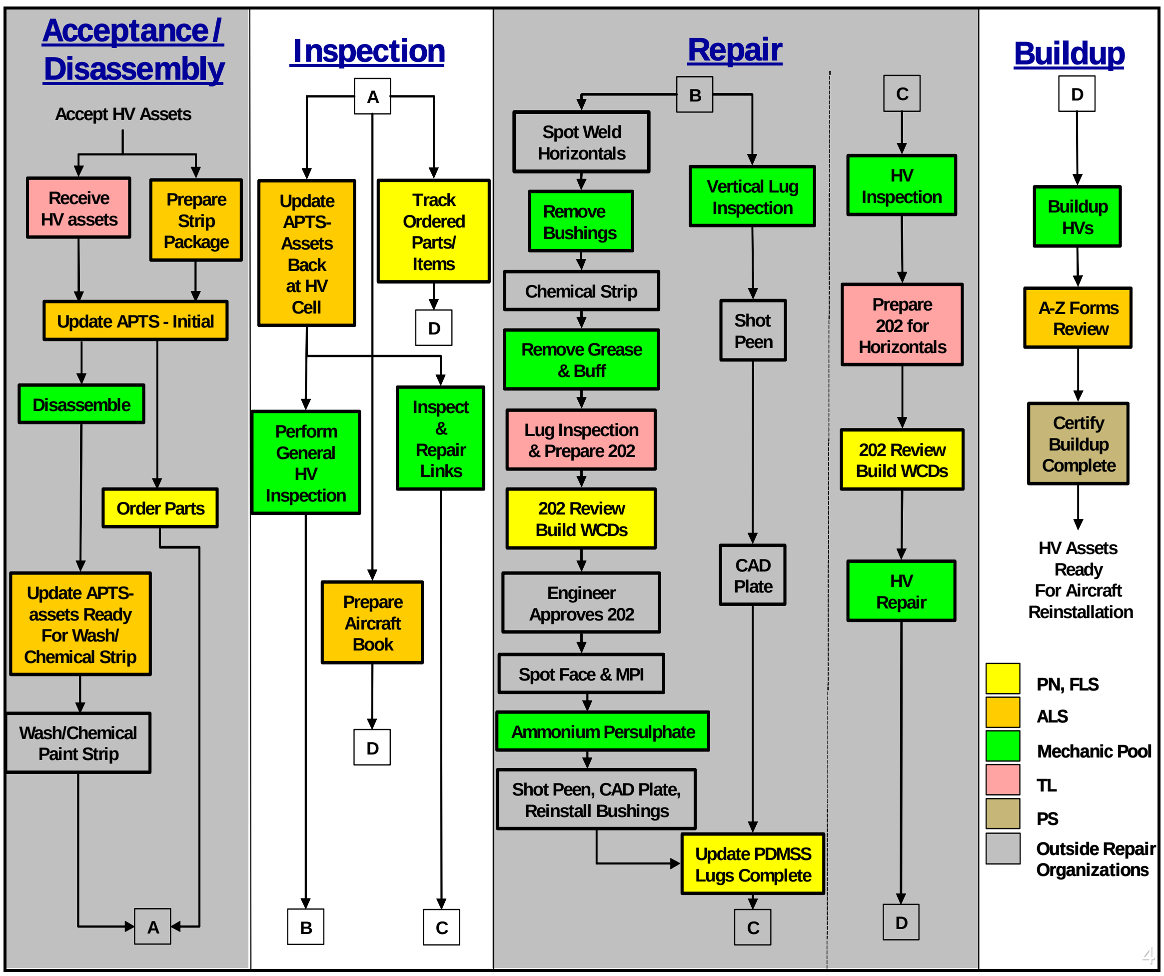


Figure 16. Intervention 6, Horizontal and Vertical Stabilizers Repair Cell Model's Milestones and Tasks

The workers assigned to the Mechanic Pool position require training and certification to complete disassembly, inspection, repair, and buildup tasks. Cross-training of mechanics increases understanding of the HV repair process. Additional training time affects the Mechanic Pool's *skill* capabilities and settings. Therefore, within the model, the Mechanic Pool position possesses medium Aircraft Mechanic Skills and medium Sheet Metal Mechanic Skills.

This intervention is designed to increase learning and sharing of information, knowledge, and experience among position personnel. Additionally, this intervention is anticipated to make accomplishing disassembly, inspection, repair, and buildup tasks more efficient, since only one position (versus three positions) is now responsible for these tasks. Thus, project duration, cost, and risk are expected to decrease. As one position becomes accountable for all mechanic tasks, indirect work time is also predicted to decrease. With 23 mechanics working together and relying on each other to complete repair tasks, the amounts of exceptions generated by the model, while presumed to be handled quickly by the position, are expected to increase.

7. Intervention 7—Retirement Intervention

In 2007, the 76th Maintenance Wing offered voluntary retirement incentives (under the federal government's Voluntary Separation Incentive Pay program) to retirement-eligible personnel as part of the Wing's reshaping efforts to match the workforce with workload requirements (Daniel, 2007). This intervention simulates and helps identify the effect on the HV Repair Cell if another retirement incentive program is offered. According to the HV Repair Cell's shop supervisor, two sheet metal mechanics and one aircraft mechanic are eligible to retire between 30 September 2007 and 30 September 2009.

To model this intervention, the following four parameters are changed: *team experience* from medium to low, *project exception probability* from 5% to 10%, *functional exception probability* from 5% to 10%, and *communication probability* from 20% to 40%. Refer to Appendix A for the general property panel settings for Intervention 7.

Parameter changes represent the increase of overall information sharing, transfer, and interaction required to accomplish interdependent tasks. After three experienced members of the HV Repair Cell retire, organizational experience will decrease. Future HV Repair Cell personnel have less experience with flight controls repair processes and tasks. Thus, the updated 10% *team experience* parameter accounts for positions processing information more slowly and coordinating more often.

The 10% *project exception probability* characterizes the environment when three new mechanics enter the organization. A higher *project exception probability* parameter represents additional amounts of exceptions that will occur as new members learn HV repair procedures. Additionally, the 10% *functional exception probability* value denotes the higher probability that repair tasks will fail and generate rework for all dependent tasks when new employees join the organization.

Finally, the 40% communication probability value signifies that, on any given day, there is a 40% chance position members need to communicate something about the task-in-progress to position members responsible for another linked task. (Note: the *FTE* setting is not lowered within the AM7, AM2, or SM2 positions. The researchers presume the HV Repair Cell will gain replacement mechanics from other repair cells as part of reshaping the workforce or modifying workload requirements).

Similar to Intervention 4, project duration, project cost, and project risk for Intervention 7 are predicted to increase as new HV Repair Cell personnel learn repair tasks and how to communicate with current HV Repair Cell personnel. As stress on the flight controls repair system increases, the amount of exceptions generated by the model is expected to increase extensively.

THIS PAGE INTENTIONALLY LEFT BLANK

IV. RESULTS

A. INTRODUCTION

This chapter is divided into three sections: an evaluation of the baseline model, an analysis of the output parameters calculated, and a detailed breakdown of the seven interventions modeled.

B. BASELINE MODEL EVALUATION

The duration of the critical path required to accomplish flight controls maintenance is calculated to be 34.32 days, on average. Flight controls repair duration predicted by the model closely reflects the real-world duration provided by HV Repair Cell leaders. The model's prediction of flight controls repair time is within 1.9% of the existing 35-day average repair time. An approximate estimation for the baseline model improves the likelihood that running simulations will provide credible results. Therefore, the HV Repair Cell baseline model may be used as a starting point to develop interventions and analyze subsequent flight controls repair modifications.

C. OUTPUT PARAMETERS

The eight output parameters evaluated include: simulated project duration, direct work time, indirect work time (including rework time, coordination time, exception-handling wait time), total direct and indirect work time, total project cost, total functional and project exception time (including functional exception work and project exception work), project risk, and position backlog (Table 2 includes a sample illustration of output parameters). The parameters selected for evaluation are expected to have the most impact on HV Repair Cell processes and operations.

1. Simulated Project Duration

Simulated project duration is the amount of time, on average, the entire HV Repair Cell process takes to complete. This includes all maintenance and administrative

tasks for one set of KC-135 horizontal and vertical stabilizers. Project duration for each intervention and the baseline model is compared quantitatively and qualitatively with regard to risk and cost tradeoffs.

2. Direct Work Time

Direct work time measures the amount of time positions consume as they perform HV Repair Cell tasks before handling any exceptions generated by the model. Direct work time for each intervention and the baseline model is compared quantitatively and qualitatively with regard to risk and time tradeoffs.

3. Indirect Work Time

Total indirect or "hidden" work time incorporates rework time, coordination time, and exception-handling wait time.

a. Rework Time. Rework time is the time all positions need during the flight controls repair process to carry out rework generated by the simulation. This time measures the impact if a driver task fails, causing rework time for all dependent tasks linked to the driver task by one of the HV Repair Cell model's four rework links. Rework time for each intervention and the baseline model is evaluated quantitatively and qualitatively with regard to risk and cost tradeoffs.

b. Coordination Time. Coordination time is the amount of time positions spend attending meetings and processing information requests from other HV Repair Cell positions. If HV Repair Cell personnel do not possess previous experience to complete repair and administrative tasks, more communication and information-sharing is required, and the model generates more coordination time. Coordination time for each intervention is contrasted with the baseline model quantitatively and qualitatively with regard to risk and resource opportunity costs.

c. Exception-handling Wait Time. This output parameter is also known as decision wait time. Exception-handling wait time measures the time positions consume waiting for a response from their supervisor about how to resolve functional or project exceptions generated by the model. If the supervisor is managing other tasks or positions

and becomes backlogged, personnel may make a default decision (ignore or quickly fix the error) and cause project risk to escalate. Exception-handling wait time for each intervention and the baseline model is compared quantitatively and qualitatively pertaining to risk and cost tradeoffs.

4. Total Direct and Indirect Work Time

Total direct and indirect work time is the sum of direct work time plus all indirect work time (including rework, coordination, and exception-handling wait times). Total direct and indirect work time for each intervention is weighed against the baseline model quantitatively and qualitatively.

5. Total Project Cost

Total project cost is examined for each intervention and compared to the baseline model's total project cost. The model allows entry of *fixed cost* for each represented task (if known) and the *salary* of each position (if known). The default *fixed cost* setting is $0 for each task. The default *salary* setting for each position is $50 per hour. Although the "true" cost of conducting the HV repair tasks and employing HV Repair Cell positions is not modeled for this research, both default settings ($0 and $50 respectively) are used in the HV Repair Cell model to monitor relative changes.

Using the default settings allows the researchers to assess relative change in total project cost for each intervention as compared to the baseline model's total project cost. By increasing and decreasing costs, researchers can illustrate the financial impact of instituting organizational design modifications. Total project cost (the sum of direct work cost, rework cost, coordination cost, and exception-handling wait cost) is compared quantitatively and qualitatively with regard to risk and time opportunity costs.

6. Total Functional and Project Exception Time

Total functional and project exception time is the sum of the time for positions to complete work on exceptions (rework) generated by the model's *functional exception probability* and *project exception probability* settings.

a. Functional Exception Time. This value represents the amount of time HV Repair Cell positions consume repairing specific tasks that fail and require rework.

b. Project Exception Time. This output value records the time that positions take repairing failed tasks and dependent tasks (attached in the HV Repair Cell model by *rework links).*

Total functional and project exception time for each intervention and the baseline model are compared quantitatively and qualitatively.

7. Project Risk

According to the *SimVision Users' Guide* (eProjectManagement, 2003), project risk represents the probability horizontal and vertical stabilizer components repaired during the HV repair process are not integrated at the end of the HV repair process because they have defects following rework and exception-handling. The *Guide* states project risk values typically range from 0.01 to 0.99. For example, a 0.4 value indicates multiple failures are not being reworked by flight controls personnel. Moreover, risk can never equal 1.0 and can only equal 0.0 if no exceptions in the HV repair process occur.

The project risk output reflects the model's initial input parameters, number of project exceptions generated, rework and coordination wait times, and inability of supervisors to quickly perform exception-handling. The *project exception probability* input for each model creates the model's project risk output. Model settings for *project exception probability* are 0.05 for the baseline and all interventions except Interventions 4 and 7, in which the settings are 0.10.

After running the simulation for the baseline model and each intervention, a low project risk value indicates successful integration on average, while a high project risk value indicates unsuccessful integration on average. Project risk for each intervention and the baseline model is compared quantitatively and qualitatively with regard to cost and time tradeoffs.

8. Position Backlog

Position backlog depicts the number of days of direct and indirect work a position has yet to accomplish. The position summary statistics provided by POWer 3.0a software include the maximum backlog time for each position and the date maximum backlog begins. Positions with elevated backlog may increase the probability of longer simulated project duration and higher project risk. Both the position with the highest position backlog and the amount of backlog for that position are presented for each intervention and the baseline model to assess shifts in responsibility and backlog differences.

D. BREAKDOWN OF INTERVENTIONS

This section summarizes the results of the seven interventions applied to the baseline model. Appendix J provides a comparative snapshot of the baseline model and interventions' numerical and relative (increase or decrease) output parameter results. In addition, Appendix J presents the differences between each intervention and the baseline in days, hours, and as a percentage of the baseline's output.

With regards to percentages, Table 3 depicts how the differences between intervention and baseline models are assessed within the Chapter IV, Results section:

Value (X)	Level of Relevance
$X < 1\%$	No Relevant Difference
$1\% \leq X < 5\%$	Weakly Relevant Difference
$5\% \leq X < 10\%$	Relevant Difference
$X > 10\%$	Highly Relevant Difference

Table 3. Output Value Levels of Relevance

1. Intervention 1—Employ One Additional Sheet Metal Mechanic

Intervention 1 adds another sheet metal mechanic to the current resource pool of 14 mechanics. Table 4 illustrates a comparison of the baseline model and the intervention.

Numerical Output	Baseline Model	Intervention 1	% Change
	Starting Point	Add One SM Mechanic	
Simulated Project Duration (days)	34.32	33.90	-1.22%
Direct Work Time (days)	130.52	130.52	0.00%
Indirect (Hidden) Work Time (days):	30.85	31.43	1.87%
Rework Time (days)	*5.03*	*5.14*	*2.24%*
Coordination Time (days)	*18.31*	*18.72*	*2.23%*
Exception-Handling Wait Time (days)	*7.51*	*7.57*	*0.75%*
Total Direct & Indirect (Hidden) Time (days)	161.38	161.95	0.36%
Total Project Cost ($)	$60,627.98	$60,841.87	0.35%
Total Functional & Project Exception Time (days)	8.74	8.71	-0.30%
Functional Exception Work (days)	*7.95*	*7.82*	*-1.61%*
Project Exception Work (days)	*0.77*	*0.88*	*13.14%*
Project Risk	0.07	0.08	16.48%
Position Backlog (days)	2.87	2.85	-0.64%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	

Table 4. Comparison of Baseline Model and Intervention 1

a. Simulated Project Duration. The researchers predicted this modification would reduce overall HV repair process time (simulated project duration). The intervention results support this prediction, as project duration decreases from 34.32 days (274.56 hours) to 33.9 days (271.2 hours). This reduction is considered weakly relevant because the 3.36-hour decrease is only 1.22% shorter than the baseline model's simulated project duration.

b. Direct Work Time. The amount of direct work time for Intervention 1 is equal to direct work time for the baseline model—both are 130.52 days. This result indicates that adding an additional sheet metal mechanic does not affect the amount of direct work to be completed during the HV repair process. The number of responsible tasks assigned to the position remains unchanged.

c. Indirect Work Time. On the other hand, adding another sheet metal mechanic increases the amount of total indirect work time. Hidden work time (including rework, coordination, and exception-handling times) grows from 30.85 days (246.8

hours) to 31.43 days (251.44 hours). This 4.64-hour difference is a 1.87% increase over the baseline model and considered weakly relevant. The change suggests extra sheet metal mechanics performing maintenance create additional rework opportunities and coordination requirements with supervisors and coworkers. Furthermore, additional mechanics increase the probability inquiries and questions will be required of supervisors (i.e., exception-handling).

d. Total Direct and Indirect Work Time. Total direct and indirect work time for Intervention 1 is 161.95 days, which is 4.62 hours higher than the baseline model's 161.38 days. Although this 0.36% increase equates to an irrelevant difference, the law of diminishing marginal returns may explain the rise. By applying the law of diminishing marginal returns, the researchers can demonstrate that, beyond some point, each additional mechanic yields less and less additional output. Only so many mechanics can physically work on and repair stabilizers at a given time. Thus, adding another sheet metal mechanic to decrease project duration may not be worth the cost of generating more indirect (hidden) work.

e. Total Project Cost. Total project cost for Intervention 1 increases to $60,841.87 from the baseline's $60,627.98—a $213.89 (0.35%) difference. The relative change in project cost is influenced by the cost associated with increased rework (2.24% higher), coordination (2.23% higher), and exception-handling (0.75% higher) wait time.

f. Total Functional and Project Exception Time. Total functional and project exception time reduces from 8.74 days to 8.71 days. Even if the new member asks more questions of the team leader when correcting project exceptions and failed tasks, overall, more SM position members are available to perform rework than in the baseline model (14 FTEs versus 13 FTEs). For the purpose of this research, the 0.3% decrease (0.21 hours/12.6 minutes) is deemed irrelevant. Furthermore, the technology and HV repair process has not changed.

g. Project Risk. As shown in Table 4, project risk for Intervention 1 is 0.08. This is an increase of 16.48% over the baseline's project risk of 0.07; such an increase is deemed highly relevant. The risk value reflects additional risk in the system when more

workers (29 FTEs versus 28 FTEs in the baseline) participate in the repair process. Extra workers generally create more exceptions, which increases the probability the model generates more rework, coordination, and exception-handling. Higher project risk indicates a lower probability of successful HV Repair Cell integration, on average.

h. Position Backlog. Lastly, the AM2 position is the highest backlogged position in both the baseline and Intervention 1 models. While the amount of backlog reduces from 2.87 days to 2.85 days, the 0.64% reduction (0.15 hours or 9 minutes) implies there is no relevant difference.

2. Intervention 2—Combine AM2/AM7 Positions, Create AM9 Position

Intervention 2 unites AM2 with AM7 mechanics to create one AM9 position for all HV Repair Cell aircraft mechanics. Table 5 depicts Intervention 2a, Intervention 2b, and the baseline model's differences and similarities.

Numerical Output	Baseline Model	Intervention 2a	% Change	Intervention 2b	% Change
	Starting Point	Create AM9 Aircraft Mech Position (Med Skills)		Create AM9 Aircraft Mech Position (High Skills)	
Simulated Project Duration (days)	34.32	34.21	-0.34%	33.46	-2.52%
Direct Work Time (days)	130.52	127.90	-2.01%	127.90	-2.01%
Indirect (Hidden) Work Time (days):	30.85	33.24	7.75%	31.22	1.19%
Rework Time (days)	*5.03*	*4.93*	*-2.03%*	*4.96*	*-1.49%*
Coordination Time (days)	*18.31*	*18.82*	*2.80%*	*18.65*	*1.88%*
Exception-Handling Wait Time (days)	*7.51*	*9.50*	*26.36%*	*7.61*	*1.29%*
Total Direct & Indirect (Hidden) Time (days)	161.38	161.14	-0.15%	159.12	-1.40%
Total Project Cost ($)	$60,627.98	$64,767.71	6.83%	$56,739.93	-6.41%
Total Functional & Project Exception Time (days)	8.74	9.27	6.14%	8.86	1.44%
Functional Exception Work (days)	*7.95*	*8.34*	*4.94%*	*7.81*	*-1.76%*
Project Exception Work (days)	*0.77*	*0.92*	*18.25%*	*1.04*	*33.81%*
Project Risk	0.07	0.09	32.11%	0.10	40.43%
Position Backlog (days)	2.87	1.69	-41.26%	1.55	-45.99%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	TL—Team Leader		TL—Team Leader	

Note: TL position's backlog under the Baseline Model is 1.53 days

Table 5. Comparison of Baseline Model, Intervention 2a, and Intervention 2b

As described in Chapter III, Section F.2., the intervention is simulated twice to allow learning effects to occur after combining low-level-skilled AM2 aircraft mechanics with high-level-skilled AM7 aircraft mechanics. The researchers predicted shorter overall project duration and coordination time, and an increase in exception-handling and wait time as AM2 members learn new tasks and ask questions.

a. Simulated Project Duration. The Intervention 2a results confirm a decrease in total project duration to 34.21 days when compared to the baseline's 34.32 days. This 55.8-minute reduction (or 0.34% improvement) is deemed to have no relevant difference. For the Intervention 2b run, total project duration further decreases 2.52% from the baseline to 33.46 days. This improvement is regarded as weakly relevant. Intervention 2b's project duration is the second lowest of the seven interventions (Intervention 6 has the shortest duration and is discussed later). It is 6.92 hours faster than the baseline and 6 hours faster than the Intervention 2a simulation.

b. Direct Work Time. Intervention 2a's output shows that direct work time shrinks by 2.63 days (from 130.52 days to 127.90 days)—a weakly relevant 2.01% reduction. Intervention 2b direct work time is the same as Intervention 2a. These results suggest that combining personnel and tasks under the AM9 position decreases the amount of direct work completed during the HV repair process. Flight controls repair and administrative tasks formerly assigned to eight separate positions (Figure 6) are now assigned to seven positions (Figure 13) and may be more efficiently performed.

c. Indirect Work Time. As shown by Table 5, total indirect work time (sum of rework, coordination, and exception-handling wait times) for Intervention 2a climbs 3.61 days to 33.24 days from the baseline's 30.85 days. This overall 7.75% rise is deemed relevant. In comparison, total indirect time for Intervention 2b only climbs 2.96 hours (to 31.22 days) from the baseline. This 1.19% increase over the baseline's 30.85 days is considered weakly relevant.

The indirect work time results demonstrate the impact of combining positions that possess different skill levels. Total indirect time for Intervention 2b is 2.02 days lower than Intervention 2a—a relevant improvement of 6.08%. This improvement suggests that

once all nine aircraft mechanics possess high-level skills, the amount of rework, coordination, and exception-handling wait time in the HV repair process should improve.

For both intervention runs, rework time decreases, coordination time increases, and exception-handling wait time increases relative to the baseline model. As depicted in Table 5, the most relevant increase is observed under exception-handling wait time. The baseline's 7.51 days jumps 26.36% to 9.5 days with the Intervention 2a run, but only 1.29% to 7.61 days with the Intervention 2b run.

Intervention 2a involves two aircraft mechanics increasing from low to medium skills and seven aircraft mechanics decreasing from high to medium skills. Conversely, Intervention 2b contains nine aircraft mechanics possessing high skills. The reduced rework time displayed by Interventions 2a and 2b suggests that improving the low-level-skilled AM2 mechanics to either medium-level or high-level decreases the total amount of rework experienced within the HV Repair Cell. Additionally, both the increased coordination time and exception-handling wait time depicted by the two intervention results reflect the effort involved to generate and process additional information requests.

d. Total Direct and Indirect Work Time. The change in total direct and indirect work time from the baseline to Intervention 2a shows no relevant difference—with a 0.15% reduction (by 1.87 hours) from the baseline's 161.38 days to 161.14 days. For Intervention 2b, the change in total direct and indirect work time (to 159.12 days from the baseline) is a weakly relevant 1.4% reduction (by 18.07 hours). For these given time reductions, the primary difference is attributed to the decrease in direct work time, as total indirect work time increases in both intervention runs.

e. Total Project Cost. The total project cost for Intervention 2a increases relevantly by 6.83% to $64,767.71 from the baseline's cost of $60,627.98. In contrast, the total project cost for Intervention 2b decreases relevantly by 6.41% to $56,739.93. These results suggest it is less expensive to realign tasks formerly performed by eight positions to fewer positions (now seven)—as long as the newly created AM9 position includes aircraft mechanics with high skills, not medium or low skills. Intervention 2b experiences the second lowest project cost below Intervention 5, which is discussed later.

f. Total Functional and Project Exception Time. When compared to the baseline model, total functional and project exception time for Intervention 2a is relevantly higher—with 6.14% more time (9.27 days versus 8.74 days). For Intervention 2b, total functional and project exception time also increase, but by a weakly relevant difference of 1.44% to 8.86 days.

Breaking down the total functional and project exception time into individual components, Intervention 2a reveals both a higher amount of functional exception work as positions repair specific failed tasks (8.34 days versus 7.95 days) and a higher amount of project exception work as positions repair interdependent failed tasks (0.92 day versus 0.77 day). In contrast to the Intervention 2a run, Intervention 2b reveals a higher amount of project exception work (1.04 days versus the baseline's 0.77 day), but a lower amount of functional exception work (7.8 days versus the baseline's 7.95 days). These differences suggest the most project exceptions and least functional exceptions occur when there are only seven positions and the AM9 position possesses aircraft mechanics with high skills.

g. Project Risk. Project risk increases from 0.07 to 0.09 for Intervention 2a and from 0.07 to 0.10 for Intervention 2b. These results imply project risk grows after the AM9 position is created, and fewer positions (seven versus eight) become responsible for the same number of HV repair tasks. Additionally, when AM9 mechanics become responsible for repairing linkages, disassembly, and buildup (see Figure 14), there is a higher probability of errors and initiation of information requests as more mechanics are required to work together.

Project risk also reflects the increased coordination and exception-handling wait times demonstrated after new AM9 task responsibilities take affect (as opposed to the previous division of labor within the baseline that indicates lower risk). Intervention 2b generates the second highest project risk value following Intervention 7, which has the highest project risk value of 0.12 and is discussed in Chapter III, Section D.7.g. Higher project risk indicates that, on average, there is a lower probability of successful HV Repair Cell integration.

h. Position Backlog. For the final output parameter, the amount of backlog in Intervention 2a decreases 41.26% to 1.69 days from the baseline's 2.87 days. For Intervention 2b, backlog diminishes even more to 1.55 days—a highly relevant difference (45.99%) from the baseline's backlog.

The highest backlogged position (formerly the AM2 position at 2.87 days) shifts to the TL position for both Intervention 2a (1.69 days) and 2b (1.55 days). Under the baseline model, the TL position backlog is 1.53 days. Both Intervention 2a and 2b increase the TL position backlog by 10.5% and 1.61% respectively. However, the overall backlog time improvement implies the new AM9 position does not become backlogged beyond 1.69 days with either medium-level or high-level skills. In addition, the results indicate once the new AM9 position is created, the TL position receives more exception-handling inquiries than under baseline model conditions.

3. Intervention 3—Change *Centralization* from Medium to Low

Intervention 3 is designed to show the effect if leaders change the level of responsibility for decision-making within the HV Repair Cell. To demonstrate this shift in organizational practice, the *centralization* parameter is changed from medium to low, which causes organizational decision-making to become more decentralized in lower-level management. This change is predicted to increase project risk and reduce repair process time, rework, coordination, and exception-handling wait time. Table 6 presents a comparison of the baseline model and the intervention.

Numerical Output	Baseline Model	Intervention 3	% Change
	Starting Point	Change Centralization from Med to Low	
Simulated Project Duration (days)	34.32	34.15	-0.49%
Direct Work Time (days)	130.52	130.52	0.00%
Indirect (Hidden) Work Time (days):	30.85	29.83	-3.33%
Rework Time (days)	*5.03*	*4.92*	*-2.24%*
Coordination Time (days)	*18.31*	*18.15*	*-0.85%*
Exception-Handling Wait Time (days)	*7.51*	*6.76*	*-10.09%*
Total Direct & Indirect (Hidden) Time (days)	161.38	160.35	-0.64%
Total Project Cost ($)	$60,627.98	$60,224.56	-0.67%
Total Functional & Project Exception Time (days)	8.74	8.64	-1.15%
Functional Exception Work (days)	*7.95*	*7.82*	*-1.64%*
Project Exception Work (days)	*0.77*	*0.81*	*3.93%*
Project Risk	0.07	0.08	20.51%
Position Backlog (days)	2.87	2.87	0.00%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	

Table 6. Comparison of Baseline Model and Intervention 3

a. Simulated Project Duration. The results show the total project duration decreases from 34.32 days to 34.15 days. This reduction of only 1.35 hours is a 0.49% change from the baseline; therefore, the simulation shows an irrelevant difference.

b. Direct Work Time. The amount of direct work time for Intervention 3 is the same as the baseline model of 130.52 days. This result reflects that changing the level of *centralization* for the HV Repair Cell model will not affect any of the task durations or position parameters. Therefore, decentralizing decision-making does not affect the amount of direct work time performed.

c. Indirect Work Time. The intervention results demonstrate a lower total indirect time—down from 30.85 days to 29.83 days, a weakly relevant difference of 3.33%. Table 6 shows rework time, coordination time, and exception-handling wait time fall (as compared to the baseline model) by 2.24%, 0.85%, and 10.09% respectively. These outputs suggest that moving the level of decision-making responsibility within the

HV Repair Cell to lower-level subordinate positions decreases the amount of rework, coordination, and exception-handling wait time.

d. Total Direct and Indirect Work Time. The sum change in total direct work and indirect work time from the baseline model is a decrease of 1.03 days—from 161.38 days to 160.35 days. This 0.64% difference is deemed irrelevant.

e. Total Project Cost. The total project cost for Intervention 3 decreases by $403.42, from $60,627.98 to the amount of $60,224.56. This 0.67% change in total project cost demonstrates there is no relevant difference. The small change in cost is attributable to the small net decreases in rework, coordination, and exception-handling wait times. This is a byproduct of employees not having to appeal to supervisors for many decisions.

f. Total Functional and Project Exception Time. The total functional and project exception time changes from 8.74 days to 8.64 days, a weakly relevant difference of 1.15%. Further examination shows project exception work time increases 0.24 hours (3.93% difference), and functional exception work time decreases 1.04 hours (1.64% difference).

g. Project Risk. Table 6 shows project risk for Intervention 3 increases to 0.08. Compared to the baseline risk of 0.07, this 20.51% difference in risk is regarded as highly relevant. This result suggests risk increases when the worker-level (i.e., the ALS, PN, FLS, AM2, AM7, and SM positions designated with *st* role assignments) does not wait for the TL or PS supervisors to decide how to handle exceptions. In a situation of decreased centralization, workers are more apt to ignore or quickly fix errors that occur in HV repair process. Increased project risk indicates that, on average, there is a lower probability of successful HV Repair Cell integration.

h. Position Backlog. The amount of backlog for Intervention 3 remains the same as the baseline model at 2.87 days, and the AM2 position remains the highest backlogged position in both the baseline and Intervention 3 models. These results indicate that decentralizing decision-making within the HV Repair Cell should neither increase the amount of backlog nor change the highest backlogged position.

4. Intervention 4—Increase *Functional Exception Probability* to 10%

Intervention 4 simulates the effects of increased stress on the flight controls repair process, in this case as a result of higher-than-normal stabilizer corrosion damage. High corrosive damage impacts diagnosis, repair time, and effort to generate new repair procedures. These changes introduce more exceptions and exception-handling time into standardized work processes. To emulate this scenario, the *functional exception probability* parameter value is increased from 5% to 10%. This increase causes the model to generate more exceptions, which requires supervisors to handle more exception-handling inquiries from workers. Additionally, the probability that repair tasks will fail due to errors and require rework becomes higher.

Overall project duration, project cost, and project risk are predicted to increase as the HV Repair Cell initiates new operating procedures. As strain on the flight controls system increases, the amount of exceptions are expected to increase considerably. Table 7 provides an illustration of the baseline model and Intervention 4.

Numerical Output	Baseline Model	Intervention 4	% Change
	Starting Point	Functional Exception from 5% to 10%	
Simulated Project Duration (days)	34.32	34.98	1.92%
Direct Work Time (days)	130.52	130.52	0.00%
Indirect (Hidden) Work Time (days):	30.85	43.36	40.53%
Rework Time (days)	*5.03*	*10.06*	*99.99%*
Coordination Time (days)	*18.31*	*19.41*	*6.01%*
Exception-Handling Wait Time (days)	*7.51*	*13.89*	*84.81%*
Total Direct & Indirect (Hidden) Time (days)	161.38	173.88	7.75%
Total Project Cost ($)	$60,627.98	$65,543.84	8.11%
Total Functional & Project Exception Time (days)	8.74	16.61	90.15%
Functional Exception Work (days)	*7.95*	*15.71*	*97.57%*
Project Exception Work (days)	*0.77*	*0.89*	*14.93%*
Project Risk	0.07	0.08	17.52%
Position Backlog (days)	2.87	2.98	3.66%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	

Table 7. Comparison of Baseline Model and Intervention 4

a. Simulated Project Duration. Intervention 4 demonstrates total project duration increases from 34.32 days to 34.98 days, a weakly relevant 1.92% rise from the baseline model.

b. Direct Work Time. The results of Intervention 4 show the same amount of direct work time as the baseline model of 132.52 days. Since direct work time represents the amount of work positions perform on tasks before handling any exceptions, a change in the *functional exception probability* parameter does not affect the resulting direct work time measurement.

c. Indirect Work Time. Increasing the *functional exception probability* parameter generates more exceptions than occur in the baseline, which then require more rework, coordination, and exception-handling wait time. This effect is supported by Intervention 4's results—showing a highly relevant 40.53% increase in total indirect work time (43.36 days) over the baseline of 30.85 days. As illustrated in Table 7, rework time, coordination time, and exception-handling wait time rise (in comparison to the baseline) by 99.99%, 6.01%, and 84.81% respectively.

d. Total Direct and Indirect Work Time. The change of the intervention's total direct and indirect work time is 12.5 days higher than the baseline, moving from 161.38 days to 173.88 days. This 7.75% difference is considered relevant.

e. Total Project Cost. Total project cost for Intervention 4 is $65,543.84, an increase of $4,915.87 from the $60,627.98 baseline cost. This 8.11% change is relevant and may be attributable to vast increases in rework wait time, coordination wait time, and exception-handling wait time.

f. Total Functional and Project Exception Time. The total functional and project exception time for Intervention 4 rises from 8.74 days to 16.61 days, a highly relevant difference of 90.15%. Compared to the baseline's results, functional exception time is 7.76 days higher (a 97.57% change), and project exception work time is 0.12 days higher (a 14.93% change). According to the *SimVision Users' Guide* (eProjectManagement, 2003), it is natural to have disparate changes—such as a highly relevant difference in *functional exception* time—when adjusting the *functional exception*

probability. A change in this parameter causes the model to generate additional functional exceptions. Therefore, more repair tasks will fail—due to localized task errors—and require rework by the responsible position.

g. Project Risk. As shown in Table 7, project risk increases to 0.08. This 17.52% difference from the baseline project risk of 0.07 is considered highly relevant. Higher risk is a consequence of more exceptions, multiple decisions regarding these exceptions, and rework and coordination occurring throughout the repair process. Higher project risk indicates a lower probability of successful HV Repair Cell integration, on average.

h. Position Backlog. The amount of backlog increases from the baseline's 2.87 days to 2.98 days, a weakly relevant difference of 3.66%. The AM2 position remains the highest backlogged position for the baseline and Intervention 4. These results indicate that when more functional exceptions occur during the HV repair process, the AM2 position may experience additional backlog.

5. Intervention 5—Combine Intervention 2b and Intervention 3

Intervention 5 integrates the changes of Interventions 2b and 3 by combining the AM2 and AM7 aircraft mechanic positions into one AM9 aircraft mechanic position and modifying the *centralization* parameter from medium to low. These changes are predicted to create mixed results demonstrating the complex tradeoffs decision-makers encounter between time, cost, and risk.

Table 8 illustrates a comparison of the baseline model and Intervention 5; Table 9 shows the simulation results for the baseline model and Interventions 2b, 3, and 5.

Numerical Output	Baseline Model	Intervention 5	% Change
	Starting Point	Combination (AM 9 Position & Low Centralization)	
Simulated Project Duration (days)	34.32	33.51	-2.37%
Direct Work Time (days)	130.52	127.90	-2.01%
Indirect (Hidden) Work Time (days):	30.85	30.03	-2.66%
Rework Time (days)	*5.03*	*4.75*	*-5.51%*
Coordination Time (days)	*18.31*	*18.70*	*2.12%*
Exception-Handling Wait Time (days)	*7.51*	*6.58*	*-12.40%*
Total Direct & Indirect (Hidden) Time (days)	161.38	157.93	-2.14%
Total Project Cost ($)	$60,627.98	$56,280.97	-7.17%
Total Functional & Project Exception Time (days):	8.74	8.43	-3.48%
Functional Exception Work (days)	*7.95*	*7.47*	*-6.07%*
Project Exception Work (days)	*0.77*	*0.95*	*22.78%*
Project Risk	0.07	0.09	36.49%
Position Backlog (days)	2.87	1.51	-47.56%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	TL—Team Leader	

Note: TL position's backlog under the Baseline Model is 1.53 days

Table 8. Comparison of Baseline Model and Intervention 5

Numerical Output	Baseline Model	Intervention 2b	Intervention 3	Intervention 5
	Starting Point	Create AM9 Aircraft Mech Position (High Skills)	Change Centralization from Med to Low	Combination (AM 9 Position & Low Centralization)
Simulated Project Duration (days)	34.32	33.46	34.15	33.51
Direct Work Time (days)	130.52	127.90	130.52	127.90
Indirect (Hidden) Work Time (days):	30.85	31.22	29.83	30.03
Rework Time (days)	*5.03*	*4.96*	*4.92*	*4.75*
Coordination Time (days)	*18.31*	*18.65*	*18.15*	*18.70*
Exception-Handling Wait Time (days)	*7.51*	*7.61*	*6.76*	*6.58*
Total Direct & Indirect (Hidden) Time (days)	161.38	159.12	160.35	157.93
Total Project Cost ($)	$60,627.98	$56,739.93	$60,224.56	$56,280.97
Total Functional & Project Exception Time (days):	8.74	8.86	8.64	8.43
Functional Exception Work (days)	*7.95*	*7.81*	*7.82*	*7.47*
Project Exception Work (days)	*0.77*	*1.04*	*0.81*	*0.95*
Project Risk	0.07	0.10	0.08	0.09
Position Backlog (days)	2.87	1.55	2.87	1.51
Position With Highest Backlog	AM2—Links Aircraft Mechanic	TL—Team Leader	AM2—Links Aircraft Mechanic	TL—Team Leader

Table 9. Comparison of Baseline Model and Interventions 2b, 3, and 5

a. Simulated Project Duration.

(1) Compared to Baseline: Intervention 5 exhibits a 6.52-hour project duration decrease from 34.32 days to 33.51 days. This 2.37% difference is regarded as weakly relevant. Of all seven interventions, Intervention 5 has the third smallest relevance, behind Intervention 6 and Intervention 2b. The results demonstrate that by reducing the number of positions responsible for HV repair processes and by empowering lower-level subordinates to resolve issues at their level, decision-makers may reduce repair completion time.

(2) Compared to Interventions 2b and 3: Intervention 5 is 0.05 days (0.4 hours) higher than Intervention 2b—a 0.15% increase—and 0.64 days (5.12 hours) lower than Intervention 3—a 1.89% decrease. These percentage differences are regarded as irrelevant and weakly relevant respectively. The results suggest that the creation of one resource pool of aircraft mechanics has more impact on project duration than the adjustment of decision-making responsibilities.

b. Direct Work Time.

(1) Compared to Baseline: The amount of direct work time shrinks 2.62 days from 130.52 days to 127.90 days. This 2.01% reduction is weakly relevant. The small difference indicates that combining aircraft mechanics into one resource pool responsible for the same number of tasks (as the baseline model) may increase the availability of mechanics. As the likelihood of an aircraft mechanic becoming available increases, direct work spreads among mechanics slightly more efficiently than currently, and the amount of direct work time within the HV Repair Cell process decreases.

(2) Compared to Interventions 2b and 3: The direct work time for Interventions 5 is 127.90 days. This time is the same as Intervention 2b, while the time in Intervention 3 is 130.52 days (identical to the baseline model). This indicates the decrease in amount of direct work is a result of combining the aircraft mechanics and tasks into one position (AM9), but not from changing the *centralization* parameter to low. This observation may occur because repair and administrative tasks are performed more

efficiently by one resource pool. Moreover, decentralizing decision-making does not affect the amount of direct work time involved in the flight controls repair process.

c. Indirect Work Time.

(1) Compared to Baseline: Intervention 5 experiences a higher total indirect work time of 30.03 days, a weakly relevant difference of 2.66% over the baseline's 30.85 days. When compared to the baseline, rework time drops relevantly by 5.51%, and coordination time rises weakly relevantly by 2.12%. These results suggest fewer driver tasks fail and do not require as much rework. However, when tasks do fail, more communication and information-sharing is needed between positions to resolve issues. The combination of decentralizing decision-making authority and one mechanic resource pool produces a highly relevant difference of 12.4% for exception-handling wait time.

(2) Compared to Interventions 2b and 3: Total indirect work time for Intervention 5 is 30.03 days, which is lower than Intervention 2b's 31.22 days but higher than Intervention 3's 29.83 days. By examining rework, coordination, and exception-handling wait times, the researchers can help explain these results. As shown in Table 9, Intervention 5 has the lowest amount of rework time (4.75 days) when measured against Intervention 2b (4.96 days) and Intervention 3 (4.92 days). These findings indicate the synergistic effects of combining the newly created AM9 position with decentralized decision-making responsibility.

As discussed in Interventions 2 and 3 results sections respectively, reducing the number of positions (Intervention 2b) increases coordination time to 18.65 days, while a lowering the level of decision-making (Intervention 3) decreases coordination time to 18.15 days. Intervention 5's coordination time of 18.70 days is the highest among the three simulations. This result reflects the effort involved in processing additional information requests in a decentralized decision-making environment. More inquiries increase time spent coordinating between HV Repair Cell coworkers and supervisors. Additionally, coordination time appears to be the leading driver in the change of total indirect work time.

The exception-handling wait time for Intervention 5 is 6.58 days, which is lower than Intervention 2b (7.61 days) and Intervention 3 (6.76 days). Table 9 illustrates that when compared to the baseline model, Intervention 2b slightly raises the exception-handling wait time (1.29%). Intervention 3 has the reverse effect, with considerably less exception-handling wait time (10.09%), which decreases exception-handling time.

The combination of these two interventions contributes to the most reduction in exception-handling wait time among the three interventions. These findings suggest that as lower-level subordinates are empowered to make repair decisions and resolve issues at their level, HV Repair Cell leaders may expect shorter rework wait time and exception-handling wait time, but higher coordination wait time.

d. Total Direct and Indirect Work Time.

(1) Compared to Baseline: The change in total direct and indirect work time is a decrease of 3.45 days from 161.38 days to 157.93 days—a weakly relevant difference of 2.14%.

(2) Compared to Interventions 2b and 3: Overall direct and indirect work time for Intervention 2b is 1.4% less, and Intervention 3 is 0.64% less than the baseline model. Intervention 5 appears to increase the effects of the individual modifications by lowering the total direct and indirect work time beyond Interventions 2b and 3 respectively.

e. Total Project Cost.

(1) Compared to Baseline: The total project cost for Intervention 5 decreases by $4,347, from $60,627.98 to $56,280.97—a relevant 7.17% difference. Additionally, the project cost for Intervention 5 is the smallest of all seven interventions.

(2) Compared to Interventions 2b and 3: Similar to the total direct and indirect work time results, the Intervention 5 model seems to promote the effects of the two individual interventions. While Intervention 2b has 6.41% less project cost, and Intervention 3 has 0.67% less project cost, the Intervention 5 project cost is the lowest of the three interventions when compared to the baseline's project cost.

f. Total Functional and Project Exception Time.

(1) Compared to Baseline: Total functional and project exception time for Intervention 5 drops 2.43 hours, from 8.74 days to 8.43 days—a weakly relevant difference of 3.48%. Separating total time into individual components, functional exception work decreases by 6.07%, and project exception work increases by 22.78%. These percentage changes represent the impact of failed tasks and subsequent rework by either individual positions or dependently linked positions (connected by *rework links* in the model). Additionally, the Intervention 5 values for functional project work time and total functional and project exception work time are the best of all seven intervention simulations.

(2) Compared to Interventions 2b and 3: As Table 9 illustrates (and as the researchers elaborated in the respective results sections previously), Intervention 2b reveals 33.81% more project exception work and 1.76% less functional exception work than the baseline. Similarly, Intervention 3 shows 3.93% higher project exceptions and 1.64% lower functional exceptions than the baseline. These results suggest more project exceptions should be expected with seven positions (versus eight); yet, the increase may be dampened by decentralizing decision-making authority. Likewise, the results indicate even fewer functional exceptions occur when Intervention 5's design changes are applied.

g. Project Risk.

(1) Compared to Baseline: As shown in Table 8, project risk for Intervention 5 is 0.09. This increase is 36.49% over the baseline's project risk of 0.07 and deemed highly relevant. The higher output value reflects additional risk in the system when there are fewer positions in the HV Repair Cell and decentralized decision-making exists. When both of these conditions are modeled, the higher project risk indicates a lower probability of successful HV Repair Cell integration, on average.

In this intervention, more project exception work (22.78% over the baseline) causes the model to generate additional coordination time. Although Intervention 5 exhibits the third shortest project duration, third shortest indirect work time, second shortest total direct and indirect work time, smallest project cost, and

shortest total functional and project exception time, it also experiences the third highest project risk. These findings illustrate the opportunity costs of time and resource savings. The cost of lowering HV Repair Cell time and expenses may not be worth the additional risk forecasted to occur.

(2) Compared to Interventions 2b and 3: The project risk for Intervention 5 is 0.09 compared to Intervention 2b's risk of 0.10 and Intervention 3's 0.08. These results suggest that when the two individual interventions are combined, project risk is somewhat mitigated, but still more than experienced with the baseline model.

h. Position Backlog.

(1) Compared to Baseline: The amount of backlog decreasing from 2.87 days to 1.51 days is a highly relevant reduction of 47.56%. The highest backlogged position switches from AM2 in the baseline model to TL in the intervention. Under the baseline model, the TL position backlog is 1.53 days. The overall backlog improvement implies that if the TL position supervises fewer positions, and these positions possess decision-making responsibilities, the HV Repair Cell experiences less backlog. Furthermore, the results indicate that once the AM9 position is created (with all aircraft mechanics possessing high-level skills), and lower-level employees are empowered, the TL position should receive fewer exception-handling inquiries than it does under the baseline model conditions. Nonetheless, although the TL position receives less exception-handling questions and experiences less build up, these efficiencies may not be worth the impact of increased project risk on HV repair quality.

(2) Compared to Interventions 2b and 3: From the results identified in Table 9, backlog time for Intervention 5 is the lowest of the three simulations. When only the *centralization* parameter was lowered (Intervention 3), there was no change to backlog time or position. The major driver for reduced backlog time stems from lowering the number of positions (by forming the AM9 position) and moving which position is backlogged (from AM2 to TL).

6. Intervention 6—Cross-train and Create One Mechanic Pool Position

Intervention 6 explores the effects of cross-training nine aircraft and 14 sheet metal mechanics to create one "resource pool" position—with 24 mechanics responsible for disassembly, inspection, repair, and buildup tasks. Table 10 illustrates the differences and similarities between the baseline and Intervention 6.

Numerical Output	Baseline Model	Intervention 6	% Change
	Starting Point	Crosstrain/ 1 Mechanic Resource Pool	
Simulated Project Duration (days)	34.32	29.42	-14.28%
Direct Work Time (days)	130.52	125.27	-4.02%
Indirect (Hidden) Work Time (days):	30.85	26.74	-13.34%
Rework Time (days)	*5.03*	*3.64*	*-27.67%*
Coordination Time (days)	*18.31*	*17.42*	*-4.85%*
Exception-Handling Wait Time (days)	*7.51*	*5.68*	*-24.43%*
Total Direct & Indirect (Hidden) Time (days)	161.38	152.01	-5.80%
Total Project Cost ($)	$60,627.98	$60,453.35	-0.29%
Total Functional & Project Exception Time (days)	8.74	9.31	6.60%
Functional Exception Work (days)	*7.95*	*8.19*	*3.03%*
Project Exception Work (days)	*0.77*	*1.11*	*43.27%*
Project Risk	0.07	0.06	-18.68%
Position Backlog (days)	2.87	1.43	-50.18%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	TL—Team Leader	

Note: TL position's backlog under the Baseline Model is 1.53 days

Table 10. Comparison of Baseline Model and Intervention 6

As detailed in Chapter III, Section F.6., the current OC-ALC collective bargaining agreement prohibits formal cross-training. This intervention models the possible effects if cross-training was allowed and instituted by OC-ALC leaders and labor union representatives.

The intervention's modifications are predicted to increase the efficiency of disassembly, inspection, repair, and buildup tasks because only one mechanic position is

responsible for all repair tasks. The intervention's output should demonstrate a reduction in total HV repair process time and total direct and indirect work time.

a. Simulated Project Duration. The results show total project duration decreases from 34.32 days to 29.42 days. This drop of 4.9 days is 14.28% lower than the baseline model and regarded as highly relevant. The change suggests that increasing the number of mechanics capable of conducting HV repair tasks—because they possess both medium Aircraft Mechanic Skills and medium Sheet Metal Mechanic Skills—speeds up the time to complete the flight controls repair process. Project duration for Intervention 6 is the smallest of all seven interventions.

b. Direct Work Time. The amount of direct work time for Intervention 6 shrinks 5.25 days from the baseline's 130.52 days to 125.27 days, a weakly relevant change of 4.02%. This result suggests one resource pool of mechanics—as opposed to the baseline's three separate AM2, AM7, and SM positions—responsible for all repair tasks (i.e., disassembly, general HV inspection, inspection and repair of linkages, removal of bushings, grease and buff lugs, ammonium persulphate, inspection of vertical lugs, HV repair, and HV buildup) decreases the amount of direct work within the HV repair process.

c. Indirect Work Time. The output of the intervention shows less total indirect time—down from the baseline's 30.85 days to 26.74 days. This decrease of 4.11 days (32.92 hours) is a highly relevant difference of 13.34%. In comparison to the baseline model, this result implies that fewer positions responsible for repair tasks may create lower levels of rework, coordination, and exception-handling. When weighed against the baseline, rework time decreases by 27.67%; coordination time decreases by 4.85%; and exception-handling wait time decreases by 24.43%.

d. Total Direct and Indirect Work Time. The change in total direct and indirect work time for Intervention 6 from the baseline is a 9.36-day decrease from 161.38 days to 152.01 days. This 5.8% reduction is deemed relevant.

e. Total Project Cost. The total project cost for Intervention 6 decreases $174.63, from the baseline amount of $60,627.98 to $60,453.35. The 0.29% cost

difference is of no relevance. This small change in total project cost indicates that creating only one resource pool of mechanics responsible for all HV repair tasks may reduce cost, but may not be worth the opportunity costs associated with additional functional and project exceptions.

f. Total Functional and Project Exception Time. The total functional and project exception time for Intervention 6 rises from 8.74 days to 9.31 days. The 0.58 days (4.61 hours) difference of 6.6% is considered relevant.

Project exception work time (1.11 days) and functional exception time (8.19 days) are elevated by 43.27% and 3.03% respectively, contributing to the higher overall exception time.

g. Project Risk. As depicted in Table 10, project risk for Intervention 6 is 0.06. This 18.68% reduction from the baseline's project risk of 0.07 is deemed highly relevant. The difference suggests reducing the number of mechanic positions from three to one considerably lowers project risk. Lower project risk indicates a higher probability of successful HV Repair Cell integration, on average.

h. Position Backlog. The highest backlogged position switches from AM2 in the baseline model to the TL in Intervention 6. Total backlog time decreases from 2.87 days to 1.43 days. This 50.18% drop of 1.44 days (11.53 hours) is assessed as highly relevant. The reduction in total position backlog is the highest of any of the interventions modeled. Additionally, the TL position's backlog time fell by 6.82% from the amount experienced in the baseline.

7. Intervention 7—Retirement Intervention

Intervention 7 simulates the effects on the HV Repair Cell if voluntary retirement incentives are offered to eligible mechanics over the next two fiscal years. Table 11 exhibits a comparison between the intervention and the baseline model. The researchers predicted this intervention would not produce improvements in any of the eight output parameters because of the increased level of organizational stress experienced after retirements occur within the HV Repair Cell.

Numerical Output	Baseline Model	Intervention 7	% Change
	Starting Point	Retirement	
Simulated Project Duration (days)	34.32	35.03	2.06%
Direct Work Time (days)	130.52	130.52	0.00%
Indirect (Hidden) Work Time (days):	30.85	47.29	53.27%
Rework Time (days)	*5.03*	*10.27*	*104.22%*
Coordination Time (days)	*18.31*	*22.06*	*20.50%*
Exception-Handling Wait Time (days)	*7.51*	*14.95*	*99.01%*
Total Direct & Indirect (Hidden) Time (days)	161.38	177.81	10.18%
Total Project Cost ($)	$60,627.98	$67,813.97	11.85%
Total Functional & Project Exception Time (days)	8.74	17.51	100.47%
Functional Exception Work (days)	*7.95*	*15.99*	*101.08%*
Project Exception Work (days)	*0.77*	*1.51*	*94.27%*
Project Risk	0.07	0.12	81.10%
Position Backlog (days)	2.87	2.97	3.55%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	

Table 11. Comparison of Baseline Model and Intervention 7

a. <u>Simulated Project Duration</u>. The Intervention 7 results confirm the researchers' prediction, as total project duration increases from 34.32 days to 35.03 days (a rise of 5.66 hours). This 2.06% increase from the baseline model is considered weakly relevant.

b. <u>Direct Work Time</u>. Similar to Interventions 1, 3, and 4, the amount of direct work time for Intervention 7 is equal to the baseline model (130.52 days). This result implies modifying *team experience*, *project exception probability*, *functional exception probability*, and *communication probability* parameters does not influence the amount of direct work required during the HV repair process. Also, the results indicate direct work is not affected if changes are not made to any task durations or assigned responsibilities.

c. <u>Indirect Work Time</u>. Unlike direct work time, modifying property parameters in Intervention 7 creates a higher total indirect time—up from 30.85 days to 47.29 days. This increase of 16.44 days shows a highly relevant difference of 53.27%

over the baseline model. Rework time increases 104.22%; coordination time increases 20.5%; and exception-handling wait time increases 99.01%. These dramatic results suggest there is less team experience, a higher chance of functional and project exceptions, and an increased need to communicate. As less-experienced members face more exceptions, it takes longer for them to perform rework and coordinate actions. Likewise, as they ask more questions, it takes longer for supervisors to attend to exception-handling queries.

d. Total Direct and Indirect Work Time. Total direct and indirect work time for Intervention 7 increases 10.18% to 177.81 days, from the baseline's work time of 161.38 days. This change is most likely driven by the 53.27% increase in total hidden work time discussed in the previous paragraph.

e. Total Project Cost. Total project cost for Intervention 7 rises over the baseline amount by 11.85%, from $60,627.98 to $67,813.97. Additionally, this intervention shows the highest cost of all interventions and the baseline. The increase in total project cost is attributed to elevated number of exceptions, rework, coordination, and exception-handling wait times.

f. Total Functional and Project Exception Time. Total functional and project exception time rises from 8.74 days to 17.51 days, a highly relevant difference of 100.34%. Functional exception work increases 101.08%, and project exception work increases 94.27%. These increases contribute to higher overall exception-resolution time and severely affect waiting time as positions perform more rework, coordinate with each other, and generate exception-handling inquiries to supervisors.

g. Project Risk. As portrayed in Table 11, project risk for Intervention 7 is 0.12. This increase is 81.1% higher than the baseline's project risk of 0.07 and is considered highly relevant. Most likely, elevated risk reflects the reduction in team experience, presence of more exceptions, and additional communication effort required to complete assigned tasks. Higher project risk indicates a lower probability of successful HV Repair Cell integration, on average. Moreover, Intervention 7 experiences the highest project risk value of the seven interventions modeled.

h. Position Backlog. Lastly for Intervention 7, the AM2 position is the highest backlogged position, which is unchanged from the baseline model. Although the amount of backlog increases from 2.87 days to 2.97 days, this 3.55% is assessed as weakly relevant. This suggests that as stress on the flight controls repair process increases—brought on by retirement of three HV Repair Cell mechanics—the AM2 position still experiences the highest backlog. Additionally, the results indicate as experienced personnel leave the organization, the AM2 position should take longer to complete the linkage repair task.

THIS PAGE INTENTIONALLY LEFT BLANK

V. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

The results of this study are provided to assist OC-ALC leaders with managing the KC-135 aircraft's Programmed Depot Maintenance (PDM). Modeling and simulation experimentation enables leaders to preview possible organizational design changes and subsequent outcomes before expending valuable resources. Additionally, computational organizational modeling enables management to better understand troubling hotspot areas, assess whether or not expected risk is acceptable or unacceptable, and identify organizational design solutions to enhance the KC-135 flight controls repair process and throughput time.

The organizational modeling and simulation results generated by this research increase flight controls repair visibility and supply an objective awareness for KC-135 PDM decision-makers. The more visualization and utility provided, the more apt leaders (the ultimate decision-makers) are to examine potential organizational design modifications and assess inherent tradeoffs prior to executing any changes. The baseline model constructed for this study may be used by OC-ALC leaders as a starting point to provide quantitative and qualitative results of future HV Repair Cell organizational design initiatives. Furthermore, the modeling results may validate organizational design adjustments leaders already believe will improve the HV Repair Cell, but are not thoroughly convinced or prepared to implement yet.

By simulating multiple interventions for comparison against the current flight controls repair process (the baseline model), the authors facilitate the HV Repair Cell's efforts to manage project risk and conserve limited time, effort, and financial resources. Before implementing any design interventions shown to mitigate risk or decrease throughput time, HV Repair Cell leaders should consider implementation and opportunity costs. Decision-makers should weigh the tradeoffs between time, HV repair quality (project risk), and cost.

For example, adding capacity to repair positions or resources needed for repair tasks may improve HV repair task completion and throughput time. However, additional personnel may not be worth the requisite investment or infrastructure costs; thus, this option may not be a viable or optimal solution. Moreover, if mechanics are already conducting repair tasks in the best possible way, one more mechanic could cause crowding on the HV Repair Cell's shop floor. Congestion may result in decreased productivity and labor efficiency due to the law of diminishing marginal returns.

Another critical factor the decision-makers should consider before executing organizational design modifications is project quality. Overall, HV Repair Cell completion of the flight controls is closely tied to the number of functional and project exceptions encountered throughout the repair process. Reassigning tasks within the HV Repair Cell from backlogged positions to less backlogged positions may be possible, but not the most feasible or practical alternative. After task reassignment, tasks are not automatically accomplished more rapidly or without error if new personnel do not possess required skills or competency levels. Hastily implementing task reassignments may trigger unnecessary functional and project exceptions, time-consuming rework, and eventually degrade overall project quality.

While examining quality, project risk should also be assessed. For instance, by changing decision-making policies or parameters, decision-makers may or may not improve repair cycle-time. The modification of operating procedures may impact the level of risk throughout the repair process. By changing the level of *centralization* from medium to low, decision-makers may accelerate the HV team's repair operations, but increase the amount of communication required and escalate risk to an unacceptable level.

Conducting risk-management helps decision-makers prioritize and examine risks. Decisions regarding risks with potentially significant impact (e.g., if one component fails, the entire system fails) and high likelihood of occurrence should be addressed first. Next, decision-makers should address risks with lower chances of occurrence and impact potential (e.g., one component fails causing other components to fail, but not total system failure). Balancing risk within the HV Repair Cell may be difficult to measure, but is

imperative. It is important to note the researcher's assumptions during model development drive the resulting project risk values for each intervention.

Additionally, risk-management entails allocation of resources. Decision-makers should assess the opportunity costs of sacrificing something to obtain something else. For example, resources dedicated to reducing HV Repair Cell risk may be better allocated to another repair cell (e.g., KC-135 Boom Repair Cell). Again, the decision depends on the leaders' risk assessment. Ideally, risk management minimizes investment costs while maximizing the reduction of negative risk effects.

Decisions regarding speed versus risk and cost decisions are essential to optimal organizational design in the military operating environment. Leaders must consider the relationship between organizational performance improvements (e.g., reduced project duration) and risk factors. The Department of Defense emphasizes warfighter safety by managing risk. Repaired HV assets installed on the KC-135 aircraft must perform in accordance with design characteristics, operating conditions, environmental constraints, and aircrew expectations.

The demands of an aging KC-135 fleet and increasing operating and maintenance costs mandate flight controls repairs be of the highest quality. Risking aircraft safety during refueling operations to save money or time during PDM is not an option. The project's design of the flight controls repair process supports survivability, aircrew protection, and mission requirements by balancing cost and time reductions against project risk.

B. RECOMMENDATIONS

The simulation results of the seven interventions performed in this research provide 564 AMXS leaders an analysis of quantitative and qualitative information. Table 12 summarizes the rankings of the baseline and intervention models in the order of best output, second-best output, and third-best output.

The table includes rankings for each of the eight output parameters closely examined in Chapter IV, Results section: simulated project duration, direct work time,

indirect work time (including rework time, coordination time, exception-handling wait time), total direct and indirect work time, total project cost, total functional and project exception time (including functional exception work and project exception work), project risk, and position backlog.

Output Parameter	Baseline Model Output	Best Model and Output	2nd Best Model and Output	3rd Best Model and Output
Simulated Project Duration (days)	34.32	Intervention 6 29.42	Intervention 2b 33.46	Intervention 5 33.51
Direct Work Time (days)	130.52	Intervention 6 125.27	Interventions 2a, 2b, 5 127.90	Baseline, Interventions 1, 3, 4, 7 130.52
Indirect (Hidden) Work Time (days):	30.85	Intervention 6 26.74	Intervention 3 29.83	Intervention 5 30.03
Rework Time (days)	*5.03*	Intervention 6 3.64	Intervention 5 4.75	Intervention 3 4.92
Coordination Time (days)	*18.31*	Intervention 6 17.42	Intervention 3 18.15	Baseline 18.31
Exception-Handling Wait Time (days)	*7.51*	Intervention 6 5.68	Intervention 5 6.58	Intervention 3 6.76
Total Direct & Indirect (Hidden) Time (days)	161.38	Intervention 6 152.01	Intervention 5 157.93	Intervention 2b 159.12
Total Project Cost ($)	$60,627.98	Intervention 5 $56,280.97	Intervention 2b $56,739.93	Intervention 3 $60,224.56
Total Functional & Project Exception Time (days)	8.74	Intervention 5 8.43	Intervention 3 8.64	Intervention 1 8.71
Functional Exception Work (days)	*7.95*	Intervention 5 7.47	Intervention 2b 7.81	Interventions 1, 3 7.82
Project Exception Work (days)	*0.77*	Baseline 0.77	Intervention 3 0.81	Intervention 1 0.88
Project Risk	0.07	Intervention 6 0.06	Baseline 0.07	Interventions 1, 3, 4 0.08
Position Backlog (days)	2.87	Intervention 6 1.43	Intervention 5 1.51	Intervention 2b 1.55
Position With Highest Backlog	AM2—Links Aircraft Mechanic	TL—Team Leader	TL—Team Leader	TL—Team Leader

Table 12. Ranking of Output Parameters for Baseline and Each Intervention

By providing an analysis of the computational organization models simulated, the researchers (and other operators) can demonstrate objective awareness and draw attention to the importance of formal and informal communication flows and information processing. The effective transfer and sharing of information about task accomplishment,

repair processes, and administrative procedures among and between workers is critical to achieving top-quality and timely flight controls repairs.

To capitalize on this criticality and leverage the advantages of effective information-sharing, the researchers recommend the following measures be taken by HV Repair Cell leaders:

1. Address current hiring and operating regulations to pursue the allowance of formal cross-training within the HV Repair Cell.

2. Continue with informal cross-training of aircraft and sheet metal mechanics within the HV Repair Cell. Expand the number of cross-training tasks as time and effort permit.

3. Train and fully qualify the nine aircraft mechanics in disassembly, repair linkages, and buildup tasks to create one highly skilled aircraft mechanic position.

4. Identify clear expectations and develop an "HV Repair Cell Transition Plan" to prepare organization as multiple employees become retirement-eligible.

According to Table 12, Intervention 6 (a single, cross-trained mechanic resource pool) has the most number of "best output" parameters, ranking number one in six of the eight output parameters. Most predominantly, the characteristics input into the Intervention 6 model generate the best output for project duration, direct time, total direct and indirect work time, project risk, and position backlog. Within indirect work time, Intervention 6 has the lowest amount of rework, coordination, and exception-handling time.

The output from Intervention 6 strongly supports cross-training within the HV Repair Cell. OC-ALC leaders should pursue changing current hiring and operating regulations to permit formal cross-training. In the interim, the researchers suggest the production supervisor and team leader continue with informal cross-training of aircraft and sheet metal mechanics. The results from Intervention 6 may prove useful to objectively portray that potential benefits outweigh the cost of cross-training HV Repair Cell mechanics—including strongly significant time and risk improvements.

If the organization cannot negotiate formal cross-training into the CBA, the repair cell can still benefit from cross-training internally. The advantages received from less rework time and exception-handling waiting should be balanced against the potential likelihood of more functional and project exception work. Before implementing any changes, the HV production supervisor and team leader should recognize comfort levels may differ among employees learning new tasks and should understand the level of effort required to cross-train 9 aircraft mechanics and 14 sheet metal mechanics.

Intervention 5 (combining Intervention 2b's single aircraft mechanic pool and Intervention 3's decentralized decision-making) has the best output for two parameters: project cost and total functional and project exception time. This intervention is the second-best performing for direct work time, total direct and indirect time, and position backlog. Additionally, Intervention 5 is the third-best performing intervention for project duration and indirect work time. Within the indirect work-time parameter, Intervention 5 also has the second lowest amount of rework and exception-handling wait time. While Intervention 2b does not have the best output in any of the eight parameters, it does show excellent results for project duration, direct work time, total direct and indirect work time, project cost, functional exception work, and position backlog.

Employment of Intervention 5's organizational characteristics requires a certain amount of training time and effort. Therefore, the researchers recommend the HV Repair Cell begin to fully qualify and utilize all nine aircraft mechanics in the HV Repair Cell as soon as possible. The two aircraft mechanics currently dedicated to the repair linkages task should be provided training on disassembly and buildup tasks. This organizational change cannot be executed without adequate planning and should not occur too quickly. However, as low-level-skilled mechanics become medium-skilled and high-skilled personnel, the HV Repair Cell should be able to complete repairs more efficiently and rapidly.

Additionally, decision-makers will require time, restraint and trust to decide and design how to decentralize decision-making authority and empower lower-level employees. Lower levels of centralization cannot be realized without: 1) management taking effort to clearly explain supervisor expectations and "exceptions to the rule" if an

emergency arises, 2) supervisors believing in subordinates' skill-levels and exception-handling abilities, and 3) leadership training and preparing mechanics sufficiently to make good decisions, ensuring flight controls repair quality does not suffer.

Decentralized decision-making may only be achieved by a change in current behavior and commitment from higher-level supervisors. If they excessively manage subordinates, organizational Interventions 3 and 5 will not succeed. As the KC-135 fleet continues to age and demand increasingly complicated maintenance to keep it in the air, attempting to reduce turnaround time to the field at the expense of quality may not be worth the HV Repair Cell's cost to decentralize.

The results of Intervention 7 (three eligible mechanics retire) underscore the complications organizations face as multiple employees become retirement-eligible and are incentivized to retire. Before leaders move workers between divisions or organizations, they should consider the resulting percent of retirement-eligible personnel the moves will create. Considering the findings from Intervention 7 could help decision-makers explain the expected impact of future workforce reshaping efforts and help them mitigate undesirable consequences. As the numbers of retirement-eligible federal civilian employees increase, dealing with this type of organizational design decision becomes both more difficult and more important for managers.

Prior to implementing any of the aforementioned recommendations, OC-ALC decision-makers should review planned and ongoing process-improvement initiatives affecting horizontal and vertical stabilizer repair to identify any similarities to the interventions performed in this study.

In addition to the specific recommendations provided to the HV Repair Cell, the authors urge leadership to conduct future computational organizational modeling and simulation research for similar USAF aircraft maintenance organizations or in other KC-135 PDM repair cells (e.g., boom or gear maintenance cells). Further research should help decision-makers identify approaches that enrich information flow within the organizational structure and that enhance organizational performance, while they avoid undesirable effects and consequences before committing resources.

USAF transformation efforts improve warfighting capabilities to meet the ever-changing demands of the military's dynamic and budget-constrained environment. To satisfy these requirements, organizations should respond to demands quickly, maximize resources for sustainment and modernization, eliminate waste in organizational processes, and anticipate uncertainty wherever possible.

Understanding the magnitude of formal and informal communication flows and information processing between personnel upon organizational performance is fundamental to mission success. Effective communication and information-transfer between supervisors and subordinates directly impacts project completion, timeliness, and quality.

In conclusion, the more visualization and transparency provided before executing potential organizational design modifications, the better prepared decision-makers will be. The authors hope to provide value to their customer—the USAF—by highlighting and presenting the importance of computational organizational modeling. Their hope is that future transformation and AFSO21 initiatives will adopt and employ this uniquely innovative type of modeling approach.

APPENDIX A. GENERAL PROPERTY PANEL SETTINGS

A. BASELINE MODEL, INTERVENTION 1, INTERVENTION 2, AND INTERVENTION 6

PROPERTY	VALUE	UNITS
Priority	Medium	N/A
Work Day	480	min
Work Week	2400	min
Team Experience	Medium	N/A
Centralization	Medium	N/A
Formalization	Medium	N/A
Matrix Strength	Medium	N/A
Communication Probability	0.2	N/A
Noise Probability	0.01	N/A
Functional Exception Probability	0.05	N/A
Project Exception Probability	0.05	N/A
Number of Trials	1000	N/A

B. INTERVENTION 3 AND INTERVENTION 5

PROPERTY	VALUE	UNITS
Priority	Medium	N/A
Work Day	480	min
Work Week	2400	min
Team Experience	Medium	N/A
Centralization	Low	N/A
Formalization	Medium	N/A
Matrix Strength	Medium	N/A
Communication Probability	0.20	N/A
Noise Probability	0.01	N/A
Functional Exception Probability	0.05	N/A
Project Exception Probability	0.05	N/A
Number of Trials	1000	N/A

C. INTERVENTION 4

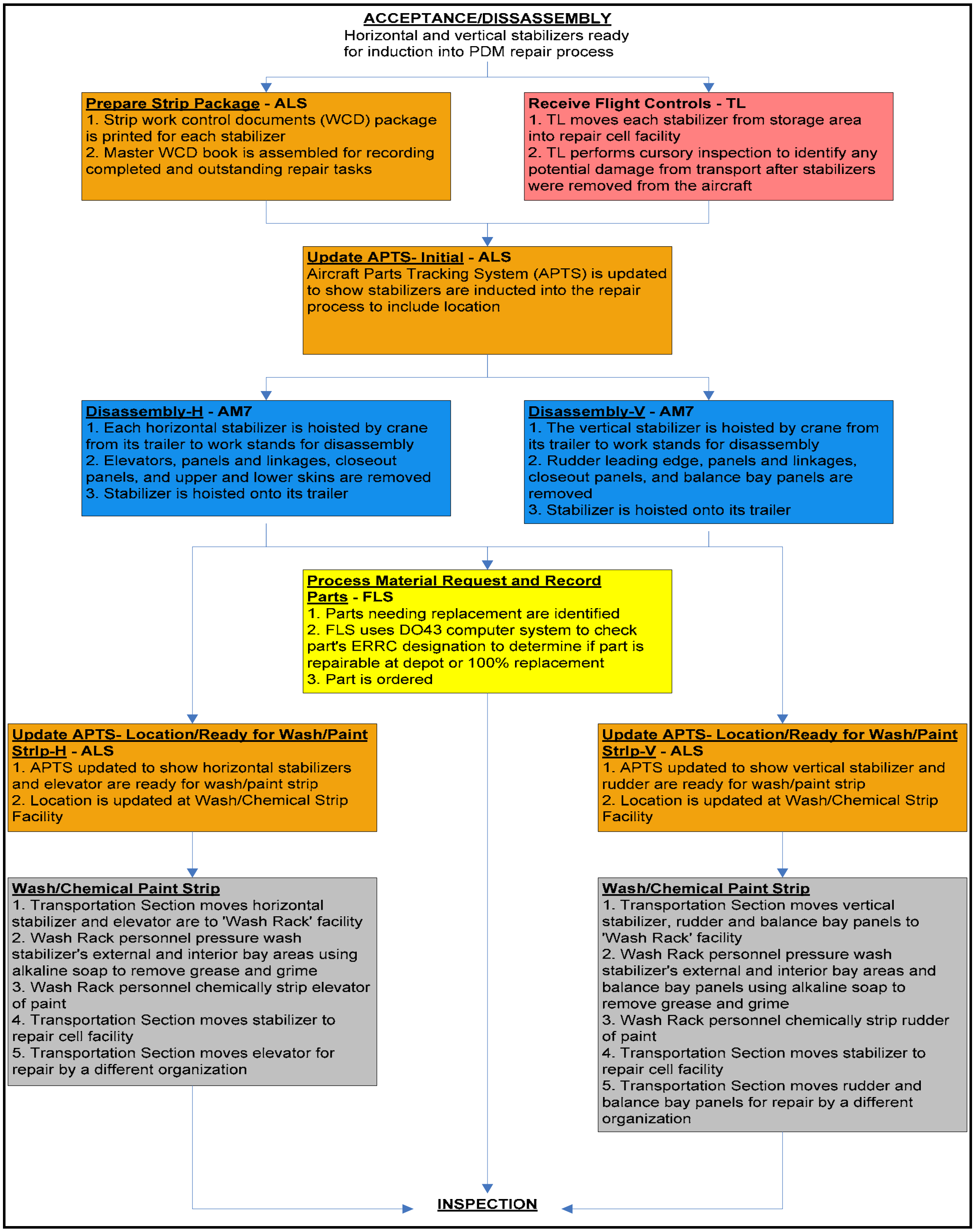
PROPERTY	VALUE	UNITS
Priority	Medium	N/A
Work Day	480	min
Work Week	2400	min
Team Experience	Medium	N/A
Centralization	Medium	N/A
Formalization	Medium	N/A
Matrix Strength	Medium	N/A
Communication Probability	0.20	N/A
Noise Probability	0.01	N/A
Functional Exception Probability	0.10	N/A
Project Exception Probability	0.05	N/A
Number of Trials	1000	N/A

D. INTERVENTION 7

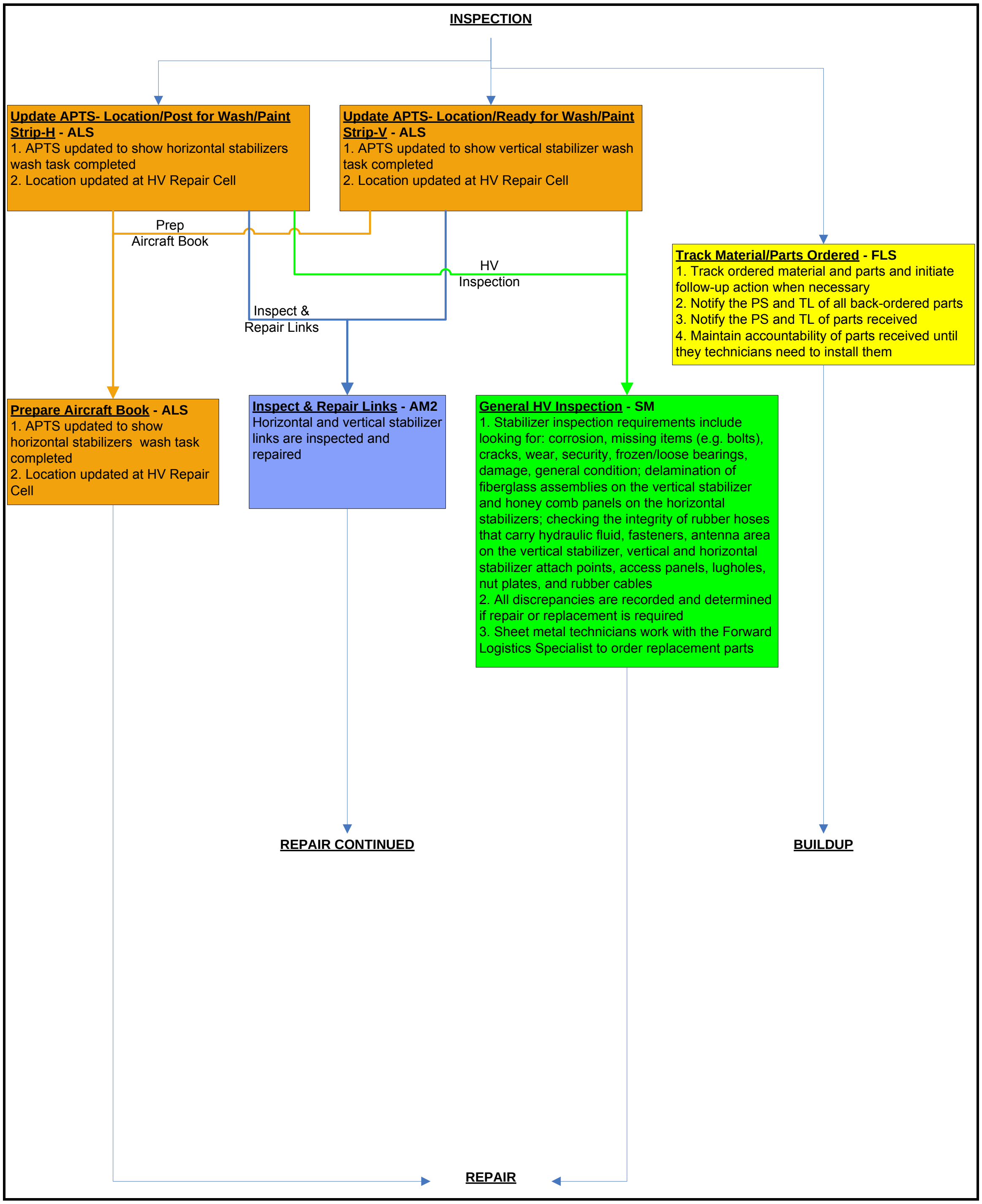
PROPERTY	VALUE	UNITS
Priority	Medium	N/A
Work Day	480	min
Work Week	2400	min
Team Experience	Low	N/A
Centralization	Medium	N/A
Formalization	Medium	N/A
Matrix Strength	Medium	N/A
Communication Probability	0.40	N/A
Noise Probability	0.01	N/A
Functional Exception Probability	0.10	N/A
Project Exception Probability	0.10	N/A
Number of Trials	1000	N/A

APPENDIX B. DETAILED DESCRIPTION OF MILESTONES, TASKS, AND SUB-TASKS

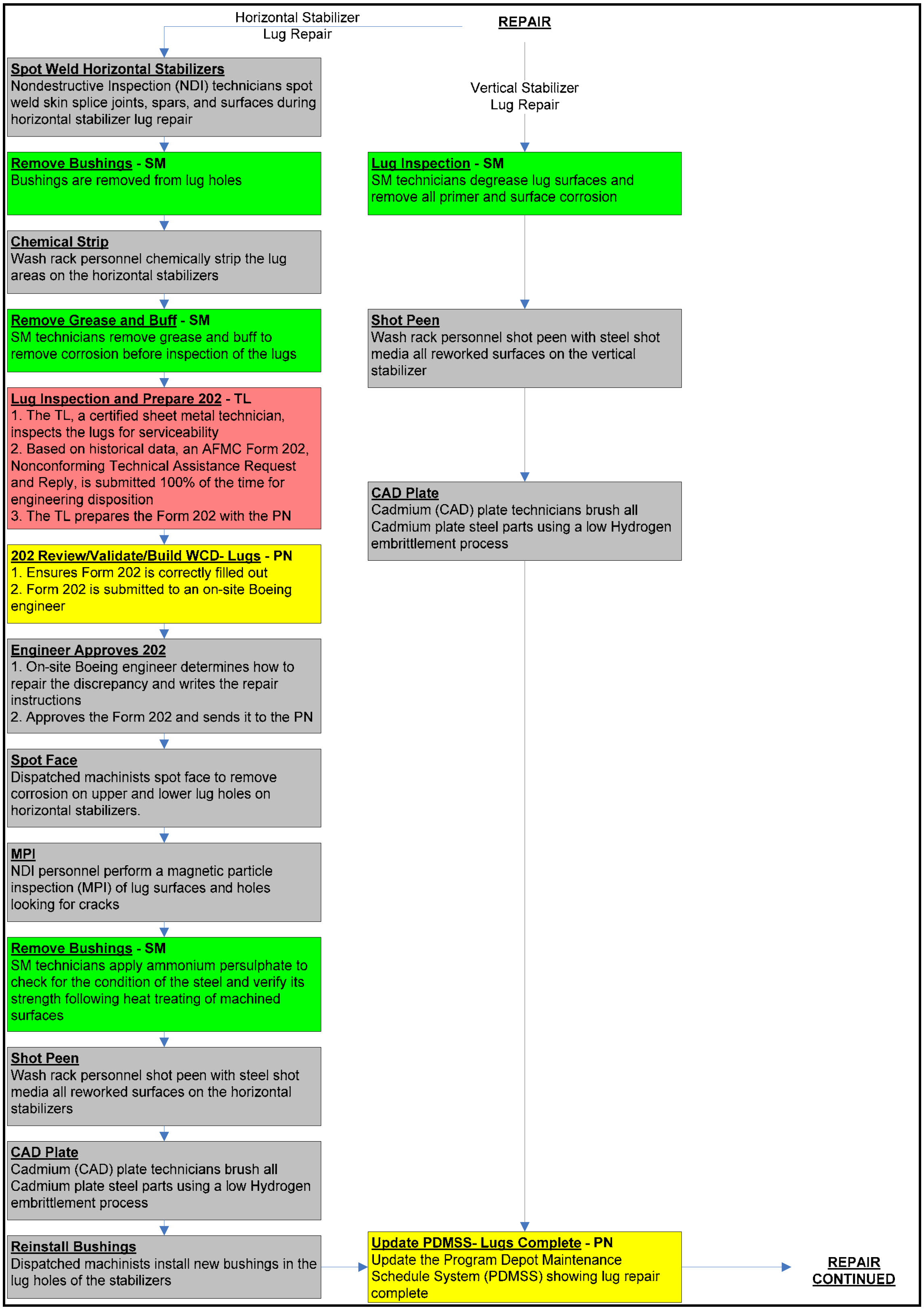
A. ACCEPTANCE/DISASSEMBLY



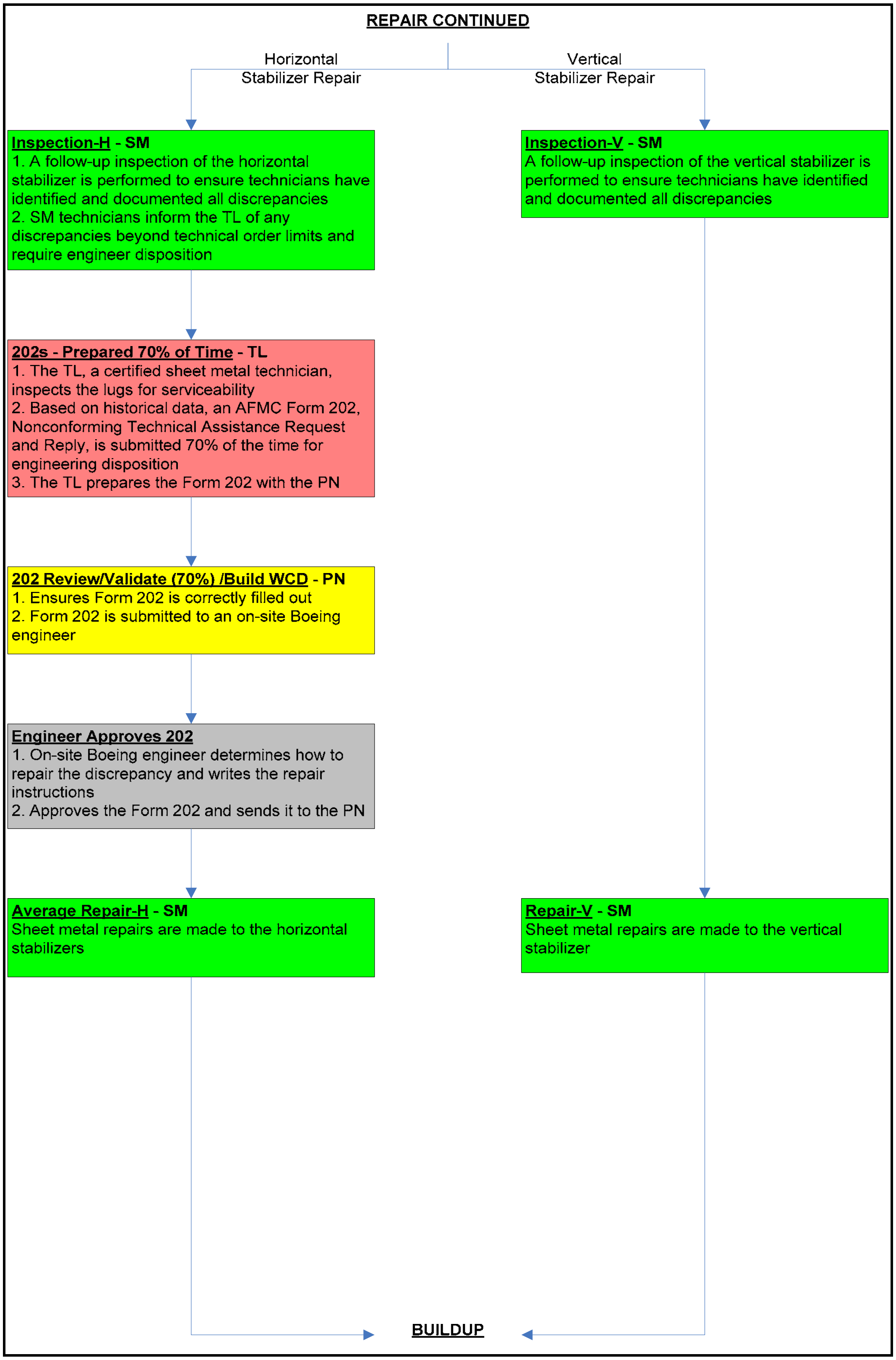
B. INSPECTION



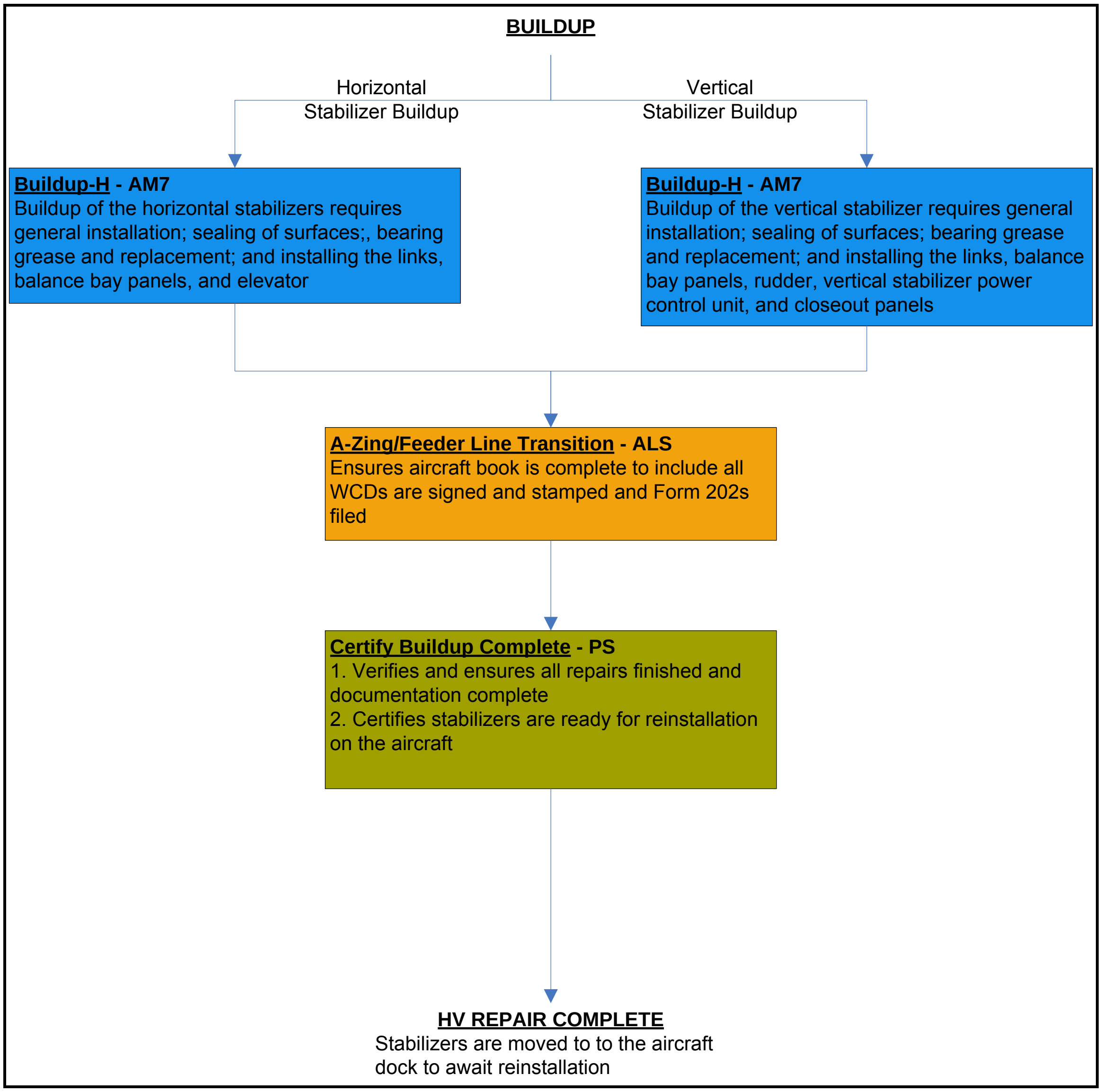
C. REPAIR


REPAIR
Horizontal Stabilizer Lug Repair
Spot Weld Horizontal Stabilizers
Nondestructive Inspection (NDI) technicians spot weld skin splice joints, spars, and surfaces during horizontal stabilizer lug repair
Remove Bushings - SM
Bushings are removed from lug holes
Chemical Strip
Wash rack personnel chemically strip the lug areas on the horizontal stabilizers
Remove Grease and Buff - SM
SM technicians remove grease and buff to remove corrosion before inspection of the lugs
Lug Inspection and Prepare 202 - TL
1. The TL, a certified sheet metal technician, inspects the lugs for serviceability
2. Based on historical data, an AFMC Form 202, Nonconforming Technical Assistance Request and Reply, is submitted 100% of the time for engineering disposition
3. The TL prepares the Form 202 with the PN
202 Review/Validate/Build WCD- Lugs - PN
1. Ensures Form 202 is correctly filled out
2. Form 202 is submitted to an on-site Boeing engineer
Engineer Approves 202
1. On-site Boeing engineer determines how to repair the discrepancy and writes the repair instructions
2. Approves the Form 202 and sends it to the PN
Spot Face
Dispatched machinists spot face to remove corrosion on upper and lower lug holes on horizontal stabilizers.
MPI
NDI personnel perform a magnetic particle inspection (MPI) of lug surfaces and holes looking for cracks
Remove Bushings - SM
SM technicians apply ammonium persulphate to check for the condition of the steel and verify its strength following heat treating of machined surfaces
Shot Peen
Wash rack personnel shot peen with steel shot media all reworked surfaces on the horizontal stabilizers
CAD Plate
Cadmium (CAD) plate technicians brush all Cadmium plate steel parts using a low Hydrogen embrittlement process
Reinstall Bushings
Dispatched machinists install new bushings in the lug holes of the stabilizers
Vertical Stabilizer Lug Repair
Lug Inspection - SM
SM technicians degrease lug surfaces and remove all primer and surface corrosion
Shot Peen
Wash rack personnel shot peen with steel shot media all reworked surfaces on the vertical stabilizer
CAD Plate
Cadmium (CAD) plate technicians brush all Cadmium plate steel parts using a low Hydrogen embrittlement process
Update PDMSS- Lugs Complete - PN
Update the Program Depot Maintenance Schedule System (PDMSS) showing lug repair complete
REPAIR CONTINUED

D. REPAIR (CONTINUED)



E. BUILDUP


BUILDUP
Horizontal Stabilizer Buildup
Vertical Stabilizer Buildup
Buildup-H - AM7
Buildup of the horizontal stabilizers requires general installation; sealing of surfaces;, bearing grease and replacement; and installing the links, balance bay panels, and elevator
Buildup-H - AM7
Buildup of the vertical stabilizer requires general installation; sealing of surfaces; bearing grease and replacement; and installing the links, balance bay panels, rudder, vertical stabilizer power control unit, and closeout panels
A-Zing/Feeder Line Transition - ALS
Ensures aircraft book is complete to include all WCDs are signed and stamped and Form 202s filed
Certify Buildup Complete - PS
1. Verifies and ensures all repairs finished and documentation complete
2. Certifies stabilizers are ready for reinstallation on the aircraft
HV REPAIR COMPLETE
Stabilizers are moved to to the aircraft dock to await reinstallation

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX C. TASK PROPERTY PANEL SETTINGS

A. RECEIVE FLIGHT CONTROLS

PROPERTY	VALUE
Task Name	Receive Flight Controls
Effort (Task Duration)	30
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Flight Control Acceptance Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

B. PREPARE STRIP PACKAGE

PROPERTY	VALUE
Task Name	Prepare Strip Package
Effort (Task Duration)	30
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

C. UPDATE APTS—INITIAL

PROPERTY	VALUE
Task Name	Update APTS—Initial
Effort (Task Duration)	15
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

D. DISASSEMBLY—H

PROPERTY	VALUE
Task Name	Disassembly—H
Effort (Task Duration)	2526
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Aircraft Mechanic Skills
Learning Days	2.63
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

E. DISASSEMBLY—V

PROPERTY	VALUE
Task Name	Disassembly—V
Effort (Task Duration)	1326
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Aircraft Mechanic Skills
Learning Days	1.38
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

F. PROCESS MATERIAL REQUEST RECORD/ORDER PARTS

PROPERTY	VALUE
Task Name	Process Material Request Record/Order Parts
Effort (Task Duration)	142.5
Effort Units	minutes
Effort Type	Work-duration
Required Skill	FLS Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

G. UPDATE APTS LOCATION/READY FOR WASH/PAINT STRIP—H

PROPERTY	VALUE
Task Name	Update APTS Location/Ready for Wash/Paint Strip—H
Effort (Task Duration)	15
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

H. UPDATE APTS LOCATION/READY FOR WASH/PAINT STRIP—V

PROPERTY	VALUE
Task Name	Update APTS Location/Ready for Wash/Paint Strip—V
Effort (Task Duration)	15
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

I. REPAIR LINKS

PROPERTY	VALUE
Task Name	Repair Links
Effort (Task Duration)	4032
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Aircraft Mechanic Skills
Learning Days	4.20
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Low
Fixed Cost	0

J. UPDATE APTS LOCATION/POST-WASH/PAINT STRIP—H

PROPERTY	VALUE
Task Name	Update APTS Location/Post-wash/Paint Strip—H
Effort (Task Duration)	15
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

K. UPDATE APTS LOCATION/POST-WASH/PAINT STRIP—V

PROPERTY	VALUE
Task Name	Update APTS Location/Post-wash/Paint Strip—V
Effort (Task Duration)	15
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

L. PREPARE AIRCRAFT BOOK

PROPERTY	VALUE
Task Name	Prepare Aircraft Book
Effort (Task Duration)	60
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

M. TRACK MATERIAL/PARTS ORDERED

PROPERTY	VALUE
Task Name	Track Material/Parts Ordered
Effort (Task Duration)	30
Effort Units	minutes
Effort Type	Work-duration
Required Skill	FLS Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

N. UPDATE PDMSS—LUG PRIORITIES

PROPERTY	VALUE
Task Name	Update PDMSS—Lug Priorities
Effort (Task Duration)	30
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

O. REMOVE BUSHINGS

PROPERTY	VALUE
Task Name	Remove Bushings
Effort (Task Duration)	216
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	0.23
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

P. REMOVE GREASE & BUFF

PROPERTY	VALUE
Task Name	Remove Grease & Buff
Effort (Task Duration)	180
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	0.19
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

Q. LUG INSPECTION & 202 PREPARE—H

PROPERTY	VALUE
Task Name	Lug Inspection & 202 Prepare—H
Effort (Task Duration)	596
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Aircraft Mechanic Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

R. 202 REVIEW/VALIDATE/BUILD WCDS—LUGS

PROPERTY	VALUE
Task Name	202 Review/Validate/Build WCDs—Lugs
Effort (Task Duration)	100
Effort Units	minutes
Effort Type	Work-duration
Required Skill	202 Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

S. AMMONIUM PERSULPHATE

PROPERTY	VALUE
Task Name	Ammonium Persulphate
Effort (Task Duration)	504
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	0.53
Priority	Medium
Requirement Complexity	High
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

T. UPDATE PDMSS LUGS COMPLETE

PROPERTY	VALUE
Task Name	Update PDMSS Lugs Complete
Effort (Task Duration)	20
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

U. LUG INSPECTION—V

PROPERTY	VALUE
Task Name	Lug Inspection—V
Effort (Task Duration)	216
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	0.23
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

V. INSPECTION—H

PROPERTY	VALUE
Task Name	Inspection—H
Effort (Task Duration)	960
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	1.00
Priority	Medium
Requirement Complexity	High
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

W. 202S—PREPARED 70% OF TIME

PROPERTY	VALUE
Task Name	202s—Prepared 70% of Time
Effort (Task Duration)	14
Effort Units	minutes
Effort Type	Work-duration
Required Skill	202 Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

X. 202 REVIEW/VALIDATE (70%)/BUILD WCDS

PROPERTY	VALUE
Task Name	202 Review/Validate (70%)/Build WCDs
Effort (Task Duration)	70
Effort Units	minutes
Effort Type	Work-duration
Required Skill	202 Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

Y. AVG REPAIR—H

PROPERTY	VALUE
Task Name	Avg Repair—H
Effort (Task Duration)	19674
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	20.49
Priority	Medium
Requirement Complexity	High
Solution Complexity	Medium
Uncertainty	Low
Fixed Cost	0

Z. INSPECTION-V/REPAIR—V

PROPERTY	VALUE
Task Name	Inspection—V/ Repair—V
Effort (Task Duration)	6270
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Sheet Metal Mechanic Skills
Learning Days	6.53
Priority	Medium
Requirement Complexity	High
Solution Complexity	Medium
Uncertainty	Low
Fixed Cost	0

AA. BUILDUP—H

PROPERTY	VALUE
Task Name	Buildup—H
Effort (Task Duration)	9534
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Aircraft Mechanic Skills
Learning Days	9.93
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Low
Fixed Cost	0

AB. BUILDUP—V

PROPERTY	VALUE
Task Name	Buildup—V
Effort (Task Duration)	6714
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Aircraft Mechanic Skills
Learning Days	6.99
Priority	Medium
Requirement Complexity	High
Solution Complexity	Medium
Uncertainty	Low
Fixed Cost	0

AC. A-ZING/FEEDER LINE TRANSITION

PROPERTY	VALUE
Task Name	A-Zing/Feeder Line Transition
Effort (Task Duration)	120
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Scheduling Skills
Learning Days	100
Priority	Medium
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AD. CERTIFY BUILDUP COMPLETE

PROPERTY	VALUE
Task Name	Certify Buildup Complete
Effort (Task Duration)	1
Effort Units	minutes
Effort Type	Work-duration
Required Skill	Supervisor Skills
Learning Days	100
Priority	High
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AE. ALS' NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	ALS' Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AF. FLS' NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	FLS' Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AG. PN'S NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	PN's Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AH. TL'S NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	TL's Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AI. AM2'S NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	AM2's Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AJ. AM7'S NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	AM7's Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AK. SM'S NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	SM's Non-touch Tasks
Effort (Task Duration)	1260
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	Low
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

AL. PS' NON-TOUCH TASKS

PROPERTY	VALUE
Task Name	PS' Non-touch Tasks
Effort (Task Duration)	430
Effort Units	minutes
Effort Type	Work-volume
Required Skill	Generic
Learning Days	100
Priority	High
Requirement Complexity	Medium
Solution Complexity	Medium
Uncertainty	Medium
Fixed Cost	0

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX D. TIME-LAG PROPERTY PANEL SETTINGS TO ACCOUNT FOR TIME DELAYS BETWEEN HV REPAIR TASKS PERFORMED BY OUTSIDE REPAIR ORGANIZATIONS

A. TIME DELAY FOR TRANSPORTATION TO WASH/CHEMICAL STRIP FACILITY AND WASH/CHEMICAL STRIPPING OF HORIZONTAL STABILIZER

PROPERTY	VALUE
From	Update APTS Location/Ready for Wash/Paint Strip—H
To	Wash/Paint Strip Complete—H
Precedence	Finish—Start
Time Lag	2400 minutes
Task(s) Time Lag Accounts For	Transportation personnel move the horizontal stabilizers to and from the wash rack. Wash Rack technicians wash or chemically strip the horizontal stabilizer.

B. TIME DELAY FOR TRANSPORTATION TO WASH/CHEMICAL STRIP FACILITY AND WASH/CHEMICAL STRIPPING OF VERTICAL STABILIZER

PROPERTY	VALUE
From	Update APTS Location/Ready for Wash/Paint Strip—V
To	Wash/Paint Strip Complete—V
Precedence	Finish—Start
Time Lag	2400 minutes
Task(s) Time Lag Accounts For	Transportation personnel move the vertical stabilizers to and from the wash rack. Wash Rack technicians wash or chemically strip the vertical stabilizer.

C. TIME DELAY FOR NONDESTRUCTIVE INSPECTION (NDI) TECHNICIAN REPAIRS ON LUGS

PROPERTY	VALUE
From	Update PDMSS—Lug Priorities
To	Remove Bushings
Precedence	Finish—Start
Time Lag	492 minutes
Task(s) Time Lag Accounts For	Nondestructive Inspection (NDI) technicians spot weld skin splice joints, spars and surfaces during horizontal stabilizer lug repair.

D. TIME DELAY FOR WASH/CHEMICAL STRIP TECHNICIAN REPAIRS ON LUGS

PROPERTY	VALUE
From	Remove Bushings
To	Remove Grease & Buff
Precedence	Finish—Start
Time Lag	204 minutes
Task(s) Time Lag Accounts For	Wash Rack personnel chemically strip the lug areas on the horizontal stabilizers.

E. TIME DELAY FOR DISPATCHED MACHINISTS AND NDI TECHNICIAN REPAIRS ON LUGS

PROPERTY	VALUE
From	202 Review/Validate/Build WCDs—Lugs
To	Ammonium Persulphate
Precedence	Finish—Start
Time Lag	2196 minutes
Task(s) Time Lag Accounts For	Dispatched machinists spot face to remove corrosion on upper and lower lug holes on horizontal stabilizers. NDI personnel perform a magnetic particle inspection of lug surfaces and holes looking for cracks.

F. TIME DELAY FOR WASH/CHEMICAL STRIP TECHNICIAN AND DISPATCHED MACHINISTS REPAIRS ON LUGS

PROPERTY	VALUE
From	Ammonium Persulphate
To	Update PDMSS Lugs Complete
Precedence	Finish—Start
Time Lag	1506 minutes
Task(s) Time Lag Accounts For	Wash rack personnel shot peen with steel shot media all reworked surfaces on the horizontal stabilizer. Cadmium plate technicians brush all Cadmium plate steel parts using a low Hydrogen embrittlement process. Dispatched machinists install new bushings in the lug holes of the stabilizers.

G. TIME DELAY FOR WASH/CHEMICAL STRIP TECHNICIAN AND DISPATCHED CADMIUM PLATE TECHNICIAN REPAIRS ON LUGS

PROPERTY	VALUE
From	Lug Inspection—V
To	Lugs Complete—V
Precedence	Finish—Start
Time Lag	1080 minutes
Task(s) Time Lag Accounts For	Wash rack personnel shot peen with steel shot media all reworked surfaces on the vertical stabilizer. Cadmium plate technicians brush all Cadmium plate steel parts using a low Hydrogen embrittlement process.

APPENDIX E. POSITION PROPERTY PANEL SETTINGS

A. PS—PRODUCTION SUPERVISOR

PROPERTY	VALUE	UNIT
Position	PS—HV Production Supervisor	N/A
Culture	Generic	N/A
Role	PM	N/A
App Exp	Medium	N/A
FTE	1.0	FTE
Salary	50	FTE/hr
Skill Ratings	202 Skills—High Aircraft Mechanic Skills—High Flight Controls Acceptance Skill—High FLS Skills—Medium Generic—Medium Scheduling Skills—Medium Sheet Metal Mechanic Skills—High Supervisor Skills—High	N/A

B. TL—TEAM LEADER

PROPERTY	VALUE	UNIT
Position	TL—Team Leader	N/A
Culture	Generic	N/A
Role	SL	N/A
App Exp	Medium	N/A
FTE	1.0	FTE
Salary	50	FTE/hr
Skill Ratings	202 Skills—High Aircraft Mechanic Skills—High Flight Controls Acceptance Skill—High FLS Skills—Medium Generic—Medium Sheet Metal Mechanic Skills—High	N/A

C. PN—PLANNER

PROPERTY	VALUE	UNIT
Position	PN—Planner	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE	0.8	FTE
Salary	50	FTE/hr
Skill Ratings	202 Skills—High Generic—Medium	N/A

D. ALS—AIRCRAFT LOGISTICS SPECIALIST/SCHEDULER

PROPERTY	VALUE	UNIT
Position	ALS—Scheduler	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE		FTE
Salary	50	FTE/hr
Skill Ratings	Generic—Medium Scheduling Skills—High	N/A

E. FLS—FORWARD LOGISTICS SPECIALIST/MATERIAL CONTROL

PROPERTY	VALUE	UNIT
Position	FLS—Forward Logistics Specialist	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE	0.8	FTE
Salary	50	FTE/hr
Skill Ratings	FLS Skills—High Generic—Medium	N/A

F. AM7—AIRCRAFT MECHANIC

PROPERTY	VALUE	UNIT
Position	AM7—Aircraft Mechanic	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE	1.0	FTE
Salary	50	FTE/hr
Skill Ratings	Aircraft Mechanic Skills—High Generic—Medium	N/A

G. AM2—AIRCRAFT MECHANIC

PROPERTY	VALUE	UNIT
Position	AM2—Link Aircraft Mechanic	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE	1.0	FTE
Salary	50	FTE/hr
Skill Ratings	Aircraft Mechanic Skills—Low Generic—Medium	N/A

H. SM—SHEET METAL MECHANIC

PROPERTY	VALUE	UNIT
Position	SM—Sheet Metal Mechanic	N/A
Culture	Generic	N/A
Role	ST	N/A
App Exp	Medium	N/A
FTE	1.0	FTE
Salary	50	FTE/hr
Skill Ratings	Sheet Metal Mechanic Skills—Medium Generic—Medium	N/A

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX F. MEETING PROPERTY PANEL SETTINGS

A. DAILY ROLL CALL MEETING

PROPERTY	VALUE	UNITS
Meeting Name	Roll Call	N/A
Priority	High	N/A
Duration	15	min
Interval	1	day
Repeating	True	N/A
Schedule-till-end	True	N/A
Meeting Time	0	hrs
First-milestone	Acceptance Complete	N/A
First-lag	0	days
Last-milestone	Acceptance Complete	N/A
Last-lag	0	days
	POSITION	**ALLOCATION**
Attendees	AM2—Links Aircraft Mechanic	1
	AM7—Aircraft Mechanic	1
	PS—Production Supervisor	1
	SM—Sheet Metal Mechanic	1
	TL—Team Leader	1

B. DAILY TURNOVER MEETING

PROPERTY	VALUE	UNITS
Meeting Name	HV Turnover Communication	N/A
Priority	High	N/A
Duration	20	min
Interval	1	day
Repeating	True	N/A
Schedule-till-end	True	N/A
Meeting Time	7.5	hrs
First-milestone	Acceptance Complete	N/A
First-lag	0	days
Last-milestone	Acceptance Complete	N/A
Last-lag	0	days
	POSITION	**ALLOCATION**
Attendees	PS—Production Supervisor	1

C. DAILY TAIL TEAM MEETING

PROPERTY	VALUE	UNITS
Meeting Name	Daily Tail Team Meeting	N/A
Priority	High	N/A
Duration	15 mins	min
Interval	1.0 day	day
Repeating	True	N/A
Schedule-till-end	True	N/A
Meeting Time	1.5 hrs	hrs
First-milestone	Acceptance Complete	N/A
First-lag	0 days	days
Last-milestone	Acceptance Complete	N/A
Last-lag	0 days	days
	POSITION	**ALLOCATION**
Attendees	ALS—Scheduler	1
	FLS—Forward Logistics Specialist	1
	PN—Planner	1
	PS—Production Supervisor	1

APPENDIX G. REWORK LINK PROPERTY PANEL SETTINGS

A. REWORK LINK FROM DISASSEMBLY OF HORIZONTAL STABILIZER TO AVERAGE REPAIR OF HORIZONTAL STABILIZER

FROM	TO	STRENGTH
Disassembly—H	Avg Repair—H	0.0030

B. REWORK LINK FROM DISASSEMBLY OF VERTICAL STABILIZER TO INSPECTION AND REPAIR OF VERTICAL STABILIZER

FROM	TO	STRENGTH
Disassembly—V	Inspection—V/ Repair—V	0.0096

C. REWORK LINK FROM DISASSEMBLY OF HORIZONTAL STABILIZER TO REPAIR LINKAGES

FROM	TO	STRENGTH
Disassembly—H	Repair Links	0.0074

D. REWORK LINK FROM DISASSEMBLY OF VERTICAL STABILIZER TO REPAIR LINKAGES

FROM	TO	STRENGTH
Disassembly—V	Repair Links	0.0074

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX H. COMMUNICATION LINK PROPERTY PANEL SETTINGS

A. COMMUNICATION LINK FROM DISASSEMBLY OF HORIZONTAL STABILIZER TO AVERAGE REPAIR OF HORIZONTAL STABILIZER

FROM	TO
Disassembly—H	Avg Repair—H

B. COMMUNICATION LINK FROM DISASSEMBLY OF VERTICAL STABILIZER TO INSPECTION AND REPAIR OF VERTICAL STABILIZER

FROM	TO
Disassembly—V	Inspection—V/ Repair—V

C. COMMUNICATION LINK FROM DISASSEMBLY OF HORIZONTAL STABILIZER TO REPAIR LINKAGES

FROM	TO
Disassembly—H	Repair Links

D. COMMUNICATION LINK FROM DISASSEMBLY OF VERTICAL STABILIZER TO REPAIR LINKAGES

FROM	TO
Disassembly—V	Repair Links

THIS PAGE INTENTIONALLY LEFT BLANK

APPENDIX I. KNOWLEDGE LINK PROPERTY PANEL SETTINGS

A. KNOWLEDGE LINK FROM TEAM LEADER TO PRODUCTION SUPERVISOR

FROM	TO	SKILL	RATING
TL—Team Leader	PS—HV Production Supervisor	202 Skills Aircraft Mechanic Skills FLS Skills Flight Controls Acceptance Skills Sheet Metal Mechanic Skills	High High Medium High High

B. KNOWLEDGE LINK FROM PLANNER TO TEAM LEADER

FROM	TO	SKILL	RATING
PN—Planner	TL-Team Leader	202 Skills	High

C. KNOWLEDGE LINK FROM SCHEDULER TO PRODUCTION SUPERVISOR

FROM	TO	SKILL	RATING
ALS—Scheduler	PS—HV Production Supervisor	Scheduling Skills	Medium

D. KNOWLEDGE LINK FROM FORWARD LOGISTICS SPECIALIST TO TEAM LEADER

FROM	TO	SKILL	RATING
FLS—Forward Logistics Specialist	TL—Team Leader	FLS Skills	Medium

E. KNOWLEDGE LINK FROM AIRCRAFT MECHANIC TO TEAM LEADER

FROM	TO	SKILL	RATING
AM7—Aircraft Mechanic	TL—Team Leader	Aircraft Mechanic Skills	High

F. KNOWLEDGE LINK FROM LINK AIRCRAFT MECHANIC TO TEAM LEADER

FROM	TO	SKILL	RATING
AM2-Link Aircraft Mechanic	TL-Team Leader	Aircraft Mechanic Skills	High

G. KNOWLEDGE LINK FROM SHEET METAL MECHANIC TO TEAM LEADER

FROM	TO	SKILL	RATING
SM-Sheet Metal Mechanic	TL-Team Leader	Sheet Metal Mechanic Skills	High

APPENDIX J. INTERVENTION RESULTS

A. OUTPUT PARAMETERS, NUMERICAL COMPARISON TO BASELINE

Numerical Output	Baseline Model Starting Point	Intervention 1 Add One SM Mechanic	Intervention 2a Create AM9 Aircraft Mech Position (Med Skills)	Intervention 2b Create AM9 Aircraft Mech Position (High Skills)	Intervention 3 Change Centralization from Med to Low	Intervention 4 Functional Exception from 5% to 10%	Intervention 5 Combination (AM 9 Position & Low Centralization)	Intervention 6 Crosstrain/ 1 Mechanic Resource Pool	Intervention 7 Retirement
Simulated Project Duration (days)	34.32	33.90	34.21	33.46	34.15	34.98	33.51	29.42	35.03
Direct Work Time (days)	130.52	130.52	127.90	127.90	130.52	130.52	127.90	125.27	130.52
Indirect (Hidden) Work Time (days):	30.85	31.43	33.24	31.22	29.83	43.36	30.03	26.74	47.29
Rework Time (days)	*5.03*	*5.14*	*4.93*	*4.96*	*4.92*	*10.06*	*4.75*	*3.64*	*10.27*
Coordination Time (days)	*18.31*	*18.72*	*18.82*	*18.65*	*18.15*	*19.41*	*18.70*	*17.42*	*22.06*
Exception-Handling Wait Time (days)	*7.51*	*7.57*	*9.50*	*7.61*	*6.76*	*13.89*	*6.58*	*5.68*	*14.95*
Total Direct & Indirect (Hidden) Time (days)	161.38	161.95	161.14	159.12	160.35	173.88	157.93	152.01	177.81
Total Project Cost ($)	$60,627.98	$60,841.87	$64,767.71	$56,739.93	$60,224.56	$65,543.84	$56,280.97	$60,453.35	$67,813.97
Total Functional & Project Exception Time (days):	8.74	8.71	9.27	8.86	8.64	16.61	8.43	9.31	17.51
Functional Exception Work (days)	*7.95*	*7.82*	*8.34*	*7.81*	*7.82*	*15.71*	*7.47*	*8.19*	*15.99*
Project Exception Work (days)	*0.77*	*0.88*	*0.92*	*1.04*	*0.81*	*0.89*	*0.95*	*1.11*	*1.51*
Project Risk	0.07	0.08	0.09	0.10	0.08	0.08	0.09	0.06	0.12
Position Backlog (days)	2.87	2.85	1.69	1.55	2.87	2.98	1.51	1.43	2.97
Position With Highest Backlog	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	TL—Team Leader	TL—Team Leader	AM2—Links Aircraft Mechanic	AM2—Links Aircraft Mechanic	TL—Team Leader	TL—Team Leader	AM2—Links Aircraft Mechanic

B. OUTPUT PARAMETERS, RELATIVE DIFFERENCE (INCREASE/DECREASE) TO BASELINE

Relative Difference (Increase/Decrease)	Baseline Model Starting Point	Intervention 1 Add One SM Mechanic	Intervention 2a Create AM9 Aircraft Mech Position (Med Skills)	Intervention 2b Create AM9 Aircraft Mech Position (High Skills)	Intervention 3 Change Centralization from Med to Low	Intervention 4 Functional Exception from 5% to 10%	Intervention 5 Combination (AM 9 Position & Low Centralization)	Intervention 6 Crosstrain/ 1 Mechanic Resource Pool	Intervention 7 Retirement
Simulated Project Duration (days)	34.32	decrease	decrease	decrease	decrease	increase	decrease	decrease	increase
Direct Work Time (days)	130.52	NO CHANGE	decrease	decrease	NO CHANGE	NO CHANGE	decrease	decrease	NO CHANGE
Indirect (Hidden) Work Time (days):	30.85	increase	increase	increase	decrease	increase	decrease	decrease	increase
Rework Time (days)	*5.03*	*increase*	*decrease*	*decrease*	*decrease*	*increase*	*decrease*	*decrease*	*increase*
Coordination Time (days)	*18.31*	*increase*	*increase*	*increase*	*decrease*	*increase*	*increase*	*decrease*	*increase*
Exception-Handling Wait Time (days)	*7.51*	*increase*	*increase*	*increase*	*decrease*	*increase*	*decrease*	*decrease*	*increase*
Total Direct & Indirect (Hidden) Time (days)	161.38	increase	decrease	decrease	decrease	increase	decrease	decrease	increase
Total Project Cost ($)	$60,627.98	increase	increase	decrease	decrease	increase	decrease	decrease	increase
Total Functional & Project Exception Time (days):	8.74	decrease	increase	increase	decrease	increase	decrease	increase	increase
Functional Exception Work (days)	*7.95*	*decrease*	*increase*	*decrease*	*decrease*	*increase*	*decrease*	*increase*	*increase*
Project Exception Work (days)	*0.77*	*increase*	*increase*	*increase*	*increase*	*increase*	*increase*	*increase*	*increase*
Project Risk	0.07	increase	increase	increase	increase	increase	increase	decrease	increase
Position Backlog (days)	2.87	decrease	decrease	decrease	NO CHANGE	increase	decrease	decrease	increase
Position With Highest Backlog	AM2—Links Aircraft Mechanic	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE

C. OUTPUT PARAMETERS, NUMERICAL DIFFERENCE FROM BASELINE IN DAYS

Numerical Difference (from Baseline) in Days	Baseline Model Starting Point	Intervention 1 Add One SM Mechanic	Intervention 2a Create AM9 Aircraft Mech Position (Med Skills)	Intervention 2b Create AM9 Aircraft Mech Position (High Skills)	Intervention 3 Change Centralization from Med to Low	Intervention 4 Functional Exception from 5% to 10%	Intervention 5 Combination (AM 9 Position & Low Centralization)	Intervention 6 Crosstrain/ 1 Mechanic Resource Pool	Intervention 7 Retirement
Simulated Project Duration (days)	34.32	-0.42	-0.12	-0.87	-0.17	0.66	-0.81	-4.90	0.71
Direct Work Time (days)	130.52	NO CHANGE	-2.63	-2.63	NO CHANGE	NO CHANGE	-2.63	-5.25	NO CHANGE
Indirect (Hidden) Work Time (days):	30.85	0.58	2.39	0.37	-1.03	12.50	-0.82	-4.11	16.43
Rework Time (days)	*5.03*	*0.11*	*-0.10*	*-0.07*	*-0.11*	*5.03*	*-0.28*	*-1.39*	*5.24*
Coordination Time (days)	*18.31*	*0.41*	*0.51*	*0.34*	*-0.16*	*1.10*	*0.39*	*-0.89*	*3.75*
Exception-Handling Wait Time (days)	*7.51*	*0.06*	*1.98*	*0.10*	*-0.76*	*6.37*	*-0.93*	*-1.84*	*7.44*
Total Direct & Indirect (Hidden) Time - (days)	161.38	0.58	-0.23	-2.26	-1.03	12.50	-3.45	-9.36	16.43
Total Project Cost ($)	$60,627.98	$213.89	$4,139.74	($3,888.05)	($403.42)	$4,915.87	($4,347.01)	($174.63)	$7,185.99
Total Functional & Project Exception Time (days):	8.74	-0.03	0.54	0.13	-0.10	7.88	-0.30	0.58	8.78
Functional Exception Work (days)	7.95	*-0.13*	*0.39*	*-0.14*	*-0.13*	*7.76*	*-0.48*	*0.24*	*8.04*
Project Exception Work (days)	0.77	*0.10*	*0.14*	*0.26*	*0.03*	*0.12*	*0.18*	*0.34*	*0.73*
Project Risk	0.07	0.01	0.02	0.03	0.01	0.01	0.02	-0.01	0.06
Position Backlog (days)	2.87	-0.02	-1.18	-1.32	NO CHANGE	0.105	-1.37	-1.44	0.10
Position With Highest Backlog	AM2—Links Aircraft Mechanic	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE

D. OUTPUT PARAMETERS, NUMERICAL DIFFERENCE FROM BASELINE IN HOURS

Numerical Difference (from Baseline) in Hours	Baseline Model Starting Point (in Hours)	Intervention 1 Add One SM Mechanic	Intervention 2a Create AM9 Aircraft Mech Position (Med Skills)	Intervention 2b Create AM9 Aircraft Mech Position (High Skills)	Intervention 3 Change Centralization from Med to Low	Intervention 4 Functional Exception from 5% to 10%	Intervention 5 Combination (AM 9 Position & Low Centralization)	Intervention 6 Crosstrain/ 1 Mechanic Resource Pool	Intervention 7 Retirement
Simulated Project Duration (hours)	274.59	-3.36	-0.93	-6.92	-1.35	5.27	-6.52	-39.21	5.66
Direct Work Time (hours)	1044.16	NO CHANGE	-21.00	-21.00	NO CHANGE	NO CHANGE	-21.00	-42.00	NO CHANGE
Indirect (Hidden) Work Time (hours):	246.82	4.62	19.13	2.93	-8.21	100.03	-6.57	-32.92	131.48
Rework Time (hours)	*40.24*	*0.90*	*-0.82*	*-0.60*	*-0.90*	*40.23*	*-2.22*	*-11.13*	*41.93*
Coordination Time (hours)	*146.46*	*3.26*	*4.09*	*2.75*	*-1.24*	*8.81*	*3.10*	*-7.10*	*30.02*
Exception-Handling Wait Time (hours)	*60.12*	*0.45*	*15.85*	*0.77*	*-6.07*	*50.99*	*-7.45*	*-14.68*	*59.52*
Total Direct & Indirect (Hidden) Time (hours)	1291.04	4.62	-1.87	-18.07	-8.21	100.03	-27.57	-74.92	131.48
Total Project Cost ($)	$60,627.98	$213.89	$4,139.74	($3,888.05)	($403.42)	$4,915.87	($4,347.01)	($174.63)	$7,185.99
Total Functional & Project Exception Time (hours):	69.89	-0.21	4.29	1.01	-0.80	63.01	-2.43	4.61	70.21
Functional Exception Work (hours)	63.62	*-1.03*	*3.14*	*-1.12*	*-1.04*	*62.07*	*-3.86*	*1.93*	*64.30*
Project Exception Work (hours)	6.20	*0.81*	*1.13*	*2.10*	*0.24*	*0.93*	*1.41*	*2.68*	*5.84*
Project Risk	0.07	0.01	0.02	0.03	0.01	0.01	0.02	-0.01	0.06
Position Backlog (hours)	22.97	-0.15	-9.48	-10.56	NO CHANGE	0.840	-10.92	-11.53	0.81
Position With Highest Backlog	AM2—Links Aircraft Mechanic	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE

E. OUTPUT PARAMETERS, PERCENTAGE CHANGE FROM BASELINE

Percentage Change from Baseline (%s)	Baseline Model	Intervention 1	Intervention 2a	Intervention 2b	Intervention 3	Intervention 4	Intervention 5	Intervention 6	Intervention 7
	Starting Point	Add One SM Mechanic	Create AM9 Aircraft Mech Position (Med Skills)	Create AM9 Aircraft Mech Position (High Skills)	Change Centralization from Med to Low	Functional Exception from 5% to 10%	Combination (AM 9 Position & Low Centralization)	Crosstrain/ 1 Mechanic Resource Pool	Retirement
Simulated Project Duration	34.32	-1.22%	-0.34%	-2.52%	-0.49%	1.92%	-2.37%	-14.28%	2.06%
Direct Work Time	130.52	NO CHANGE	-2.01%	-2.01%	NO CHANGE	NO CHANGE	-2.01%	-4.02%	NO CHANGE
Indirect (Hidden) Work Time:	30.85	1.87%	7.75%	1.19%	-3.33%	40.53%	-2.66%	-13.34%	53.27%
Rework Time	*5.03*	*2.24%*	*-2.03%*	*-1.49%*	*-2.24%*	*99.99%*	*-5.51%*	*-27.67%*	*104.22%*
Coordination Time	*18.31*	*2.23%*	*2.80%*	*1.88%*	*-0.85%*	*6.01%*	*2.12%*	*-4.85%*	*20.50%*
Exception-Handling Wait Time	*7.51*	*0.75%*	*26.36%*	*1.29%*	*-10.09%*	*84.81%*	*-12.40%*	*-24.43%*	*99.01%*
Total Direct & Indirect (Hidden) Time	161.38	0.36%	-0.15%	-1.40%	-0.64%	7.75%	-2.14%	-5.80%	10.18%
Total Project Cost	$60,627.98	0.35%	6.83%	-6.41%	-0.67%	8.11%	-7.17%	-0.29%	11.85%
Total Functional & Project Exception Time:	8.74	-0.30%	6.14%	1.44%	-1.15%	90.15%	-3.48%	6.60%	100.47%
Functional Exception Work	7.95	*-1.61%*	*4.94%*	*-1.76%*	*-1.64%*	*97.57%*	*-6.07%*	*3.03%*	*101.08%*
Project Exception Work	*0.77*	*13.14%*	*18.25%*	*33.81%*	*3.93%*	*14.93%*	*22.78%*	*43.27%*	*94.27%*
Project Risk	0.07	16.48%	32.11%	40.43%	20.51%	17.52%	36.49%	-18.68%	81.10%
Position Backlog	2.87	-0.64%	-41.26%	-45.99%	NO CHANGE	3.66%	-47.56%	-50.18%	3.55%
Position With Highest Backlog	AM2—Links Aircraft Mechanic	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE	NO CHANGE	TL—Team Leader	TL—Team Leader	NO CHANGE

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF REFERENCES

76th Aircraft Maintenance Group. (2007). *Mission statement*. Retrieved September 5, 2007, from Air Force Portal Web site: https://www.my.af.mil/gcss-af/afp40/USAF/ep/contentView.do?contentType=EDITORIAL&contentId=1225299&programId=1225454&pageId=681742&channelPageId=-1873456&parentCategoryId=-1873466.

827th Aircraft Sustainment Group. (2007). *KC-135 Stratotanker mission statement and vision*. Retrieved September 5, 2007, from Air Force Portal Web site: https://www.my.af.mil/gcss-af/afp40/USAF/ep/contentView.do?contentType=EDITORIAL&contentId=1014055&programId=1014795.

Air Mobility Command Public Affairs Office. (2006). *Factsheets: KC-135 Stratotanker*. Retrieved August 26, 2007, from http://www.af.mil/factsheets/factsheet.asp?id=110.

Collaboratory for Research on Global Projects. (2006). *POW-ER documentation for POW-ER 2.0*. Stanford University.

Daniel, J. (2007, February 9). ALC to offer retirement incentives. *Tinker Takeoff*, 65 (5). Retrieved September 10, 2007, from http://www.tinkertakeoff.com/article.htm?intRecID=13697.

Dillard, J., & Nissen, M. E. (2007). Computational modeling of project organizations under stress. [Electronic version]. *Project Management Journal*, *38*(1), 5-20. Retrieved July 18, 2007, from EBSCO database.

Dunn, K. (2007). In Paskin M., Trevino A.(Eds.), *Tanker transformation comments email, 1 June 2007* [Tanker Transformation Comments].

eProjectManagement (ePM™), LLC. (2003). *SimVision® users' guide*. Austin, Texas: ePM, LLC.

Galbraith, J. R. (1973). *Designing complex organizations*. Reading, Mass: Addison-Wesley Pub. Co.

Galbraith, J. R. (1974). *Organization design: An information processing view*. [Electronic version]. Interfaces, *4*(3), 28-36. Retrieved June 2, 2007, from EBSCO database.

Galbraith, J. R. (1977). *Organization design*. Reading, Mass: Addison-Wesley Pub. Co.

HAF/XPXC, Air Force Transformation Office. (2007). *Air Force transformation*. Retrieved June 1, 2007, from http://www.af.mil/library/transformation.

Hagan, J. J., & Slack, W. G. (2006). *Employing organizational modeling and simulation to reduce F/A-18E/F F414 engine maintenance time* (Master of Business Administration ed.). Monterey, California: Naval Postgraduate School, 2006. Retrieved April 17, 2007, from DTIC's STINET database.

Hagan, J. J., Slack, W. G., Dillard, J., & Zolin, R. (2007, March/April). You've optimized your process …: Now optimize your organization. *Defense & AT-L, 36*(2), 16-20. Retrieved April 30, 2007 from EBSCO database.

Kunz, J. C., Christiansen, T. R., Cohen, G. P., Jin, Y., & Levitt, R. E. (1998, November). The virtual design team. [Electronic version]. *Communications of the ACM, 41*(11) 84-91. Retrieved April 17, 2007, from EBSCO database.

Levitt, R. E. (2007). *Behavior files in SimVision*. Retrieved August 26, 2007, from http://epm.cc/solutions/simvision.htm.

Levitt, R. E., & Kunz, J. C. (2002, August). *Design your project organization as engineers design bridges* (CIFE Working Paper No. 73). San Francisco: Stanford University. Retrieved May 15, 2007, from Stanford University Center for Integrated Facility Engineering (CIFE) database. from http://cife.stanford.edu/Publications/index.html.

Levitt, R. E. (2004, July). Computational modeling of organizations comes of age. [Electronic version]. *Computational and Mathematical Organization Theory, 10*(2), 127-145. Retrieved April 17, 2007, from ProQuest database.

Loredo, E. N., Pyles, R. A., & Snyder, D. (2007). *Programmed depot maintenance capacity assessment tool: Workloads, capacity, and availability* (No. XCUSAF). Santa Monica, CA: RAND Corporation. Retrieved September 5, 2007, from DTIC's STINET database.

Moseley, M. T. & Wynne, M. W. (2005). *Lean across the Air Force -- process development and improvement*. Retrieved June 8, 2007, from http://www.af.mil/shared/media/document/AFD-070205-086.pdf.

Nissen, M., & Levitt, R. E. (2002, November). *Toward simulation models of knowledge-intensive work processes* (CIFE Working Paper No. 77). San Francisco: Stanford University. Retrieved April 17, 2007, from Stanford University Center for Integrated Facility Engineering (CIFE) Web site: http://www.stanford.edu/group/CIFE/Publications/index.html.

Scully, M. (2007, July). Worse than the hollow force. *Air Force Magazine Journal of the Air Force Association,* pp. 50-53.

Solis, W. M., Borseth, A., Coleman, G., Mardis, O., Thornton, K., et al. (2007, March 6). *Defense acquisitions: Air Force decision to include a passenger and cargo capability in its replacement refueling aircraft was made without required analyses* (No. GAO-07-367R). Washington DC: US Government Accountability Office. Retrieved September 5, 2007, from DTIC's STINET database.

Thomsen, J., Levitt, R. E., Kunz, J. C., Nass, C. I., & Fridma, D. (2003, November). *A trajectory for validating computational emulation models of organizations* (CIFE Working Paper No. 153). San Francisco: Stanford University. Retrieved June 8, 2007, from Stanford University Center for Integrated Facility Engineering (CIFE) Web site: http://www.stanford.edu/group/CIFE/Publications/index.html.

U.S. Office of Personnel Management. (2007). *Federal classification and job grading systems.* Retrieved September 18, 2007, from http://www.opm.gov/fedclass.

Ziezulewicz, G. (2007, July 29). Refueling wing playing larger role in transport. [Electronic version]. *Stars and Stripes: European Edition*, Retrieved September 5, 2007, from Stars and Stripes database: http://www.estripes.com/article.asp?section=104&article=55281&archive=true

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Commander
   76th Maintenance Wing
   Oklahoma City Air Logistics Center, Oklahoma

4. Commander
   76th Aircraft Maintenance Group
   Oklahoma City Air Logistics Center, Oklahoma

5. Commander
   564th Aircraft Maintenance Squadron
   Oklahoma City Air Logistics Center, Oklahoma

6. Debi Kirkpatrick
   76th Aircraft Maintenance Group
   Oklahoma City Air Logistics Center, Oklahoma

7. Debra Welch
   564th Aircraft Maintenance Squadron
   Oklahoma City Air Logistics Center, Oklahoma

8. James Wilson
   564th Aircraft Maintenance Squadron
   Oklahoma City Air Logistics Center, Oklahoma

9. Clint Gill
   Lean Chief
   76th Aircraft Maintenance Group
   Oklahoma City Air Logistics Center, Oklahoma

10. Kenneth Dunn
    Tanker Lean Office Agent
    76th Aircraft Maintenance Group
    Oklahoma City Air Logistics Center, Oklahoma

11. Garry Richey
Director of Logistics, Installations and Mission Support
Headquarters Air Education and Training Command/A4/7
Randolph Air Force Base, Texas

12. Dr. Geraldo Ferrer
Naval Postgraduate School
Monterey, California

13. Prof. John Dillard
Naval Postgraduate School
Monterey, California

14. Prof. Diana Petross
Naval Postgraduate School
Monterey, California

15. Director
Air Force Smart Operations for the 21st Century (AFSO21)
Office of the Secretary of the Headquarters Air Force
Washington, D.C.

16. Director
Strategic Management Division (HQ AFMC/A8T)
Headquarters Air Force Materiel Command
Wright-Patterson Air Force Base, Ohio

17. Chief
Transformation, Integration, and Process Improvement Division (OC-ALC/XPT)
Oklahoma City Air Logistics Center, Oklahoma